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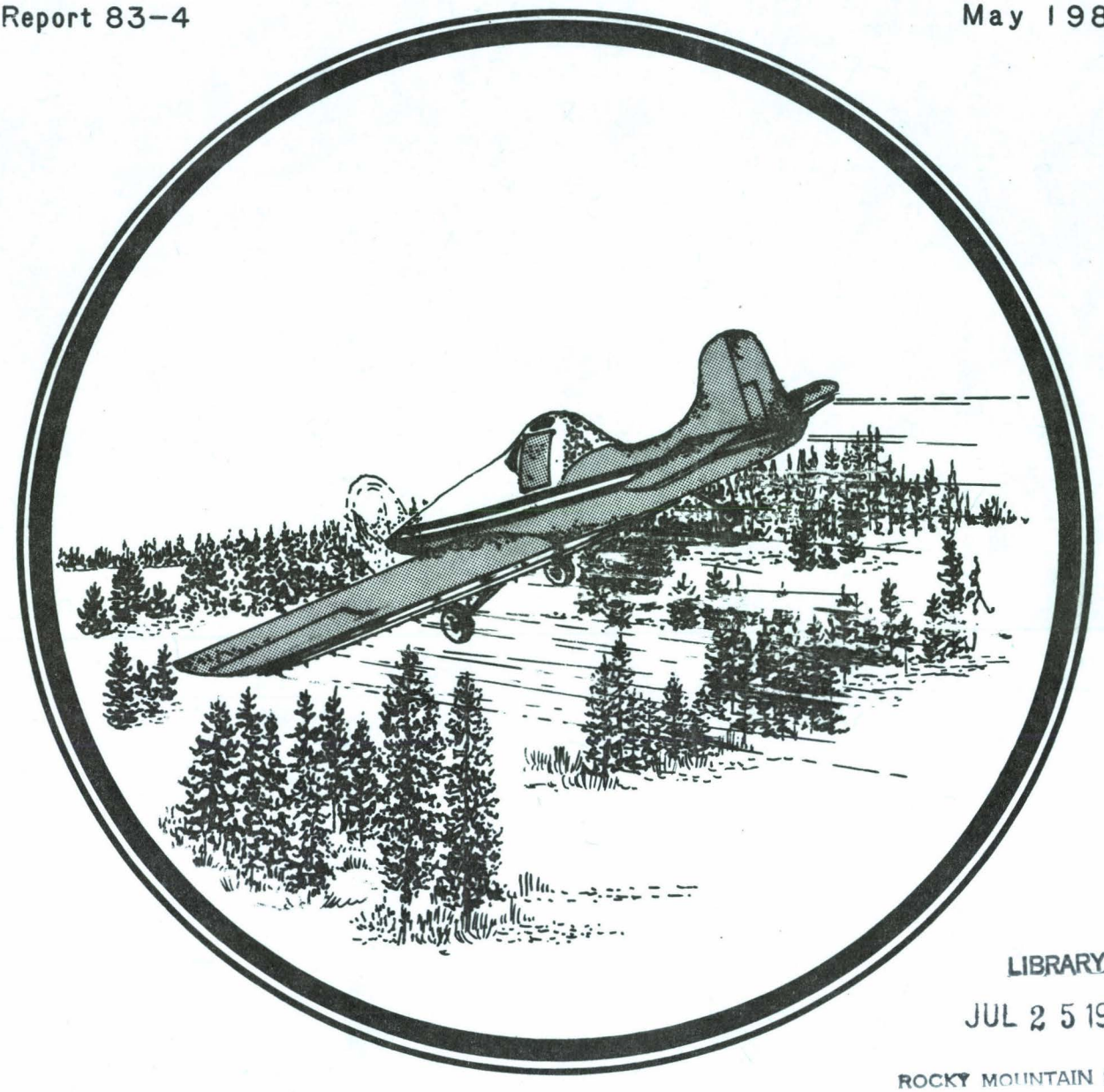
PILOT PROJECT OF *Bacillus thuringiensis* AGAINST WESTERN SPRUCE BUDWORM IN CENTRAL MONTANA, 1981

Report 83-4

May 1983



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COVER STORY

An Ayers Turbo Thrush aircraft was used to apply B.t. on 16,750 acres (6,784 hectares) near Butte, Montana for western spruce budworm control. In the recent past, most spray projects in the West have not used fixed-wing aircraft. However, to help reduce application costs, we selected a turbine powered Thrush for its demonstrated capabilities over mountain terrain and for its large payload (450 gallons (1,703 liters) maximum). Our application rate per aircraft per hour was 507 acres (205 hectares).

PILOT PROJECT OF *BACILLUS THURINGIENSIS* AGAINST WESTERN SPRUCE BUDWORM IN CENTRAL MONTANA, 1981

by

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We also acknowledge the efforts of personnel from the Butte and Whitehall Ranger Districts for providing the laboratory and field crews. We extend special thanks to the Butte Ranger District staff for their help in assisting with local arrangements. These items include time and attendance reports, cold storage facility, warehouse space, contacts with local landowners, arrangements for a temporary laboratory, message taking, and responding to the numerous daily requests for assistance.

We acknowledge the help and support of all others who took part in this project. Many project objectives were made possible through the assistance of the Bureau of Land Management, State of Montana, and private landowners who gave permission to use their holdings. Technical support was provided through representatives from Abbott Laboratories and Sandoz, Inc. Detailers from the S&PF (WO), NOAA, R-6, R-1, and MEDC spent many predawn hours collecting deposit data.

A final thanks goes to the administration at East Junior High School who donated the use of their science complex for our laboratory.

ABSTRACT

Cooperative Forestry and Pest Management conducted a pilot control project in central Montana to determine the effectiveness of two commercial formulations of *Bacillus thuringiensis* Berliner applied at 8 billion international units (BIU) per acre (19.8 BIU per hectare) when used under operational conditions against the western spruce budworm, *Choristoneura occidentalis* Freeman. Nine blocks 2,000-4,200 acres (810-1,701 hectares) were selected in areas of budworm infestation on State, private, BLM, and Forest Service lands near Butte, Montana. Three blocks were randomly assigned Dipel 4L treatment, three blocks were assigned Thuricide 16B treatment, and the remaining three served as control blocks.

Time and sequence of treatment was determined by larval development sampling in each block. Blocks were released for treatment when 50 percent of the larvae had developed to or beyond the fourth instar. A prespray population sample was collected within 24 hours of spraying from 25 three-tree cluster plots established in each block. Treating began on June 29 and ended on July 5. Spray was applied with two Ayers Turbo Thrush aircraft equipped with fulljet one-eighth 66A8W nozzles calibrated at 1 gallon per acre (1.5 liters per hectare). Dipel was applied to 8,600 acres (3,493 hectares), and Thuricide to 8,150 acres (3,301 hectares). Eight thousand acres (3,240 hectares) were used as control areas. Postspray population samples were collected at 7, 14, and 21 days following treatment. Population densities are expressed in number of larvae per 100 shoots. Following egg deposition, percent defoliation and egg mass densities were collected from each cluster tree.

Unadjusted budworm mortality at 21 days was 48 and 62 percent for Dipel and Thuricide respectively. Budworm mortality in control blocks averaged 26 percent. Percent defoliation was 33, 36, and 47 for Dipel, Thuricide, and control. Adjusted mortality for all larvae (combined) prior to the egg stage was 73 and 91 percent for Dipel and Thuricide. In 1981, percent parasitism for all defoliators in the Dipel, Thuricide, and control blocks was 21.5, 19.8, and 26.0, respectively. Egg mass densities per square meter (per square foot) in 1981 were 18.3 (5.6), 17.6 (5.4), and 38.5 (11.7) for Dipel, Thuricide, and control.

Mean budworm larvael densities in 1982 were 4.4, 3.5, and 12.7 larvae per 100 shoots for the Dipel, Thuricide, and control areas. Rearing samples showed a greater proportion of females emerging in sprayed than in control blocks (61.4 and 62.0 percent for Dipel and Thuricide compared to 52.4 percent in the controls); however, adult female weight was higher in the control blocks (126.3 mg compared to 121.3 and 113.9 mg for the Dipel and Thuricide blocks, respectively). Average percent parasitism of budworm larvae and pupae in 1982 was 5.1, 8.6, and 7.3 for the Dipel, Thuricide, and control blocks. We were unable to distinguish any effects of B.t. on individual budworm parasite species during the study. Egg mass densities in 1982 were 44.5 (13.6), 39.7 (12.1), and 78.6 (24.0) per square meter (per square foot) for Dipel, Thuricide, and control.

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INTRODUCTION

As part of a nationwide Forest Service effort, the Northern Region (R-1) conducted a pilot control project using *Bacillus thuringiensis* Berliner (B.t.) against the western spruce budworm (*Choristoneura occidentalis* Freeman) in central Montana during 1981. A sister project was conducted in the Southwestern Region (R-3). The purpose of these projects was to evaluate operational performance of two registered B.t. formulations (Dipel® 4L and Thuricide® 16B) at their recommended rates (8 BIU/acre (19.8 BIU/hectare)) across the range of this insect.

For many years DDT was the only insecticide used to control western spruce budworm outbreaks throughout much of the West. As early as 1948, budworm infestations were aerially treated with DDT. The initial effects and the long residual action of DDT usually gave excellent results, but caused great concern when applied over large forested areas. The DDT controversy ended in 1972 when DDT was withdrawn from forest use. During the early 1960's efforts were initiated to identify alternate materials. Today acephate and carbaryl are the most widely accepted and used materials for budworm management, but the quest for more effective and/or environmentally acceptable materials continues. Recent developments with biological agents have caused renewed interest in microbial insecticides for forest use. Several formulations have been registered for a wide variety of agricultural and forest uses. B.t. is a naturally occurring, aerobic, spore-forming bacterium. It is produced commercially in several formulations.

This project was designed to gather data needed to evaluate the proposed use of B.t. as an operational control agent for budworm. The safety of biological pesticides like B.t. would make an important addition to a resource manager's pest management options. B.t. would find application in sensitive areas where conventional insecticides are likely to upset some management objectives. The safety of B.t. would allow its use in sensitive locations such as along waterways, near lakes, in domestic watersheds, near inhabited areas, and in many other areas where conventional pesticides are restricted.

This report describes the conduct and procedures followed throughout the project and during a reevaluation the following year. Results are presented and summarized for the spray year (1981) and for the following year (1982) to determine long-term results. Additional data will be collected during 1983 and a supplement to this report will be prepared.

Project design and sampling procedures used here were patterned after those used in recent Forest Service pilot control projects in the West. Minor variations were made based on B.t.'s mode of action. Other changes were made to incorporate recommendations from research and a West-wide B.t. task force.

OBJECTIVES

The principal project objective was to obtain performance data on two registered formulations of B.t. on western spruce budworm populations in central Montana.

Specific tasks included:

1. Identify and attempt to resolve any problems associated with the mixing and application of two commercial formulations of B.t.

2. Determine unit cost of B.t. when used at 8 BIU per acre (19.8 BIU per hectare).

3. Measure budworm population reduction and current foliage protection immediately following application.

4. During the year following treatment, measure residual population and second-year defoliation.

5. Compare efficacy from two widely separated portions of the budworm range (Northern Rockies vs Southwest).

6. Obtain vertical aerial photographs and compare differences in subsequent damage between treated and untreated blocks (1982).

PROJECT AREA

This project was conducted in western spruce budworm infested Douglas-fir stands on portions of the Deerlodge and Beaverhead National Forests and adjacent Bureau of Land Management, State of Montana, and private lands. The project area extended from Wise River, Wise River Ranger District on the southwest to Grouse Creek, Jefferson Ranger District on the northeast (Appendix A1). This general area has a long history of budworm outbreaks which are characterized by prolonged infestations with frequent large fluctuations in population. The 1980 egg mass data forecasted moderate to heavy defoliation over much of the project area in 1981. Nine blocks, plus several alternates, were initially selected based on egg density data. Final blocks and boundary selections were made in mid-June using aerial observations, past defoliation, and early larval counts (Appendices A2 to A10).

The project area consisted primarily of Douglas-fir stands along the forest fringe between 5,000 and 7,300 feet (1,524 and 2,225 meters) elevation MSL. Forest activities in these areas include, but are not limited to, timber harvesting, grazing allotments, summer homesites, summer and winter recreation, small and big game hunting, fishing, mining, and watersheds. Descriptions of final block selections are given in Table 1.

Table 1. Elevation, acreage and treatments of B.t. blocks.

Block	Elevation in feet (meters) High	Low	Mean	Acres (hectares)	Treatment
Grouse	6,320 (1,926)	5,300 (1,615)	5,785 (1,763)	2,400 (972)	Dipel
Spire	6,840 (2,085)	5,200 (1,585)	5,920 (1,804)	3,650 (1,478)	Thuricide
Coyote	6,550 (1,996)	5,560 (1,695)	6,062 (1,848)	2,500 (1,013)	Thuricide
Whiskey	6,280 (1,914)	5,040 (1,536)	5,720 (1,743)	2,000 (810)	Thuricide
Bald	6,240 (1,901)	5,520 (1,682)	5,860 (1,786)	2,000 (810)	Dipel
Fish	7,120 (2,170)	6,080 (1,853)	6,490 (1,978)	2,000 (810)	Control
Divide	6,840 (2,085)	5,890 (1,795)	6,440 (1,963)	4,000 (1,620)	Control
Jerry	7,280 (2,219)	5,890 (1,795)	6,640 (2,024)	2,000 (810)	Control
Jimmie	7,360 (2,243)	5,540 (1,689)	6,590 (2,009)	4,200 (1,701)	Dipel

INSECTICIDES

Description

Both Dipel 4L and Thuricide 16B are commercial formulations of spores and crystalline bodies produced by the bacterium *Bacillus thuringiensis* Berliner. For B.t. to be effective it must be ingested since it has no contact action. In the hind gut pH of budworm larvae, the crystalline inclusion bodies soon dissolve releasing a toxin that paralyzes and disrupts the gut wall. Feeding may stop within 30 minutes to 2 hours. Death generally follows in 3 to 5 days. Sublethal dose effects on budworm are unknown. Unlike chemical pesticides, by their nature, B.t. formulations are very selective and thus environmentally safe. B.t. is only toxic to the larval stage of a large number of moths and butterflies (Lepidoptera). Examples include spruce budworm (east and west), gypsy moth, tent caterpillars, spring and fall cankerworm and cabbage looper. Neither product has shown any phytotoxicity when applied at recommended rates. The Environmental Protection Agency has exempted B.t. from any residual tolerance requirements on raw agricultural commodities for man and animals. The residual life of B.t. is quickly reduced by ultraviolet light. Following treatment the number of B.t. spores returns to the background level within 2 or 3 days.

Mixing and Handling

Mixing and handling responsibilities were included in the aerial application solicitation package. The contractor was required to provide batch mixing equipment and two people to mix and load. All mixing and loading were supervised by the contracting officer's representative (COR). Representatives from Abbott Laboratories and Sandoz, Inc. were available on site for technical assistance.

Batch mixing was used for characterization trials and the application phase. Twenty to 25 gallons (76 to 95 liters) of tank mix were prepared for each characterization trial. Batch size for the application phase was specified by the spray pilot. Specific load sizes were based on air temperature, elevation and topography within a block, ferry distance, fuel load, etc. Loads were generally between 300 and 400 gallons (1,136 and 1,514 liters). Batch mixing was based on the following 200 gallon (757 liter) formulas:

Dipel 4L		Thuricide 16B	
Dipel	50 gallons (189 liters)	Thuricide	100 gallons (379 liters)
Rhodamine dye	2 pounds (907 grams)	Rhodamine dye	2 pounds (907 grams)
Water	150 gallons (568 liters)	Water	100 gallons (379 liters)

Batch mixing eliminated problems associated with storage, handling and disposal of unused tank mix. Batches were mixed and loaded as needed. Under no circumstance was a tank mix to be used after 24 hours. Most loads were used within a half hour and none stood for more than an hour. The only material discarded was the daily wash water used to clean the mixing equipment and aircraft.

Acrylocoat® at 3 percent for Dipel and 1 percent for Thuricide was recommended to improve rain fastness. However, during the initial calibration trials using Dipel, serious pump problems developed. After spraying approximately 15 gallons (57 liters), the air driven pump developed a bad leak. A rubber-like film had formed between the porcelain base of the pump seal and the spring-loaded seat. After a new seal was installed, the problem recurred. Since another new seal was not available, the pump was only cleaned and reassembled. The use of Acrylocoat was discontinued. Without Acrylocoat, over 8,000 gallons (30,283 liters) of tank mix were pumped through each of two aircraft with no further problems.

Random tank samples were collected to verify product formulation and mixing procedures. Results were as follows:

Block	Material	BIU/gal. (lit.) [1/]
Grouse	Dipel	8.8 (2.3) [2/]
Spire	Thuricide	8.4 (2.2)
Coyote	Thuricide	8.0 (2.1)
Whiskey	Thuricide	8.4 (2.2)
Bald	Dipel	8.8 (2.3) [2/]
Jimmie	Dipel	8.8 (2.3) [2/]

1/ All mixes were formulated to 8.0 BIU per gallon (2.1 BIU per liter).

2/ These data were not from our mix, but from the same lot number.

Storage and Disposal

The Butte Ranger District warehouse was used to store both insecticides and dye. Access was through a locked gate. As per contract, Dipel was delivered in 2.5-gallon (9.5-liter) plastic containers and Thuricide in 5-gallon (19-liter) containers. These sizes made handling convenient, but increased our disposal problem. Empty containers were rendered nonserviceable by cutting slits along the sides. Each afternoon, all used containers and refuse were hauled to an approved landfill by a commercial disposal company.

PROJECT DESIGN

This project consisted of a single aerial application of Dipel 4L and Thuricide 16B, each at 8 BIU per gallon per acre (5.2 BIU per liter per hectare) against mid-instar western spruce budworm larvae. Each insecticide treatment was replicated three times on blocks of 2,000 to 4,200 acres (810 to 1,701 hectares). Three other 2,000- to 4,000-acre (810 to 1,620) blocks served as control treatments and were not sprayed.

Block Selection

Besides egg mass data described earlier, blocks were selected which had the best combination of the following factors:

1. Budworm population density (>15 and <45 larvae per 100 shoots).
2. Host type (>40 percent Douglas-fir).
3. Topography (gentle to moderate).
4. Vehicle access (good to excellent).

Topography and/or distance between blocks eliminated spray drift between blocks. Where possible, for ease of location and identification, block boundaries followed prominent terrain features. Breaks in type and natural clearings were also used to designate boundaries. At corners and where necessary, 9-square foot (.8-square meter) orange panels were used to mark boundaries.

Sample Clusters

Three-tree plot clusters were established within each block as the basic sampling unit. Twenty-five, 3-tree cluster locations were carefully selected and distributed throughout each block to represent both elevational and topographic variation within a block (Appendices A2 to A10). One additional tree was selected at each cluster for larval development sampling. Cluster locations were at least 2 chains (40 meters) from another cluster, block boundaries, or main roads.

Sample Trees

Sample trees were open-grown Douglas-fir, 35 to 60 feet (11 to 18 meters) tall with full crowns. Previous defoliation was generally below 25 percent. Cluster trees were located within a 1-acre (.4-hectare) area (118-foot (36-meter) radius).

Sampling Periods

Various life stage samples were collected during the following periods:

1981 a. Larval development.

b. Population density, prespray.

c. Population density, 7-day postspray.

d. Population density, 14-day postspray.

e. Population density, 21-day postspray.

f. Egg density and defoliation.

1982 a. Population density, larvae.

b. Rearing, larvae and pupae.

c. Egg density and defoliation.

FIELD PROCEDURES

1981 Larval Development Sample

Proper timing of insecticide application was dependent on an accurate determination of larval development. At 10 clusters in each block, a single-tree plot was established to monitor larval development. These

clusters were selected to represent the topographic range within each block. Development sampling began on June 11, 1981. Appendices B1 to B3 summarize development from June 11 through block release and treatment.

Two 45-cm (18-inch) branches were cut from opposite sides of midcrown, placed individually in paper bags, and transported to the laboratory for examination. When examination could not be completed the same day, foliage was stored at 39°F (4°C).

1981 Prespray Larval Population Sample

Prespray foliage samples were collected within 24 hours before treatment. Four 45-cm (18-inch) midcrown branches (one from each quadrant) were cut from each cluster tree (300 branches per block). Extreme care was taken when cutting branches to avoid dislodging larvae. All contents of the catch basket were placed in separate paper bags. Bags from each cluster were fastened together and transported to the laboratory. During bundling and transportion, care was taken to keep samples cool and out of direct sunlight. To reduce long exposure to ambient temperatures, at midday the morning collection was taken to the laboratory for processing or cold storage.

1981 Spray Deposit Sample

Spray deposit evaluation was based on amount of spray material deposited on Kromekote® cards. Rhodamine Extra S dye was added to the tank mix at 1 pound per 100 gallons (120 grams per 100 liters). Plastic card holders with Kromekote cards (together referenced as samplers) were located around cluster trees, one at each cardinal point (300 cards per block) just beneath the drip line.

Wooden stakes were used to support samplers approximately 6 inches (15 cm) above the ground. Where stakes could not be used, debris was cleared and the sampler was placed on the ground. To streamline card placement and retrieval, card holders and stakes were fitted with a strip of adhesive magnetic tape (Appendix C). This technique not only eliminated the need to staple holders to the stake but also made it possible to preload the Kromekote cards in the holder.

Samplers were placed in position at each cluster during the predawn hours before spraying began. Cards were allowed to dry for approximately one-half hour before retrieval. Because the Thuricide treated cards had an extended drying time, these cards were placed in special holders designed to prevent adjacent surfaces from touching.

1981 Postspray Larval Population Sample

Postspray samples were collected in the same manner and from the same cluster trees used for prespray. Postspray collections were made at 7, 14, and 21 days following treatment (Appendix D). Four branches per tree were cut during each period. Individually bagged branches were taken to the laboratory for examination.

1981 Defoliation Sample

During mid-September two 45-cm (18-inch) (east and west) and two 70-cm (2-inch) (north and south) midcrown branches were cut to estimate percent defoliation. Twenty-five new shoots from each of these four branches were rated using the following six-class system:

Rating	Percent defoliation
0	0
1	>0 - 25
2	26 - 50
3	51 - 75
4	76 - <100
5	100

1981 Egg Mass Sample

Two of the four branches cut for defoliation were saved for egg mass examination. The north and south branches (70-cm (28-inch)) were bagged together and transported to our laboratory in Missoula, Montana. There they were held in cold storage until examination. Foliage was examined under longwave ultraviolet light.

1982 Larval Population Sample

In 1982, a larval sample was taken to coincide with larval development during the 1981 prespray sample. Timing was based on seasonal weather patterns and subsamples of test blocks. Blocks were collected in the sequence they were released in 1981. Four 45-cm (18-inch) midcrown branches (one from each quadrant) were cut from each cluster tree (300 branches per block). Care was taken when cutting branches to avoid dislodging larvae. All contents of the catch basket were placed in a portable beating barrel (see laboratory procedures). Branches were shaken to dislodge larvae; larvae were then placed in vials of 70 percent ethyl alcohol which were brought back to Missoula, Montana for processing. The number of shoots on each branch were counted for determination of larval density. In addition, five larvae from each tree were placed in petri dishes containing foliage and were returned to the laboratory in Missoula for parasite rearing.

1982 Rearing Sample

A second collection of larvae was taken when development corresponded to that of the 21-day postspray sample in 1981. Ten spruce budworm larvae and/or pupae were collected from each 3-tree cluster. Specimens were placed in individual petri dishes; foliage was provided to feeding larvae. Care was taken not to crush or scorch insects; samples were then transported to the laboratory in Missoula, Montana for rearing.

1982 Defoliation and Egg Mass Sample

The procedures for the second-year defoliation and egg mass samples follow those described for 1981.

LABORATORY PROCEDURES

A temporary field laboratory was set up in a local junior high school science complex in Butte, Montana. This facility was occupied from June 12 through the last postspray population sample on July 29, 1981. Foliage examination for egg mass densities during September and October 1981 was conducted in the CFPM laboratory in Missoula, Montana. All 1982 collections were processed in the Missoula laboratory.

The primary functions of the field laboratory were to examine foliage samples for insect larvae and to make daily data summaries. Samples delivered to the laboratory were processed the same day or no later than end of the following day. Foliage stored overnight was held in cold storage at 39°F (4°C).

To streamline the foliage examination process, visual branch examination method was replaced by a beating technique developed by R. F. DeBoo and later improved by R. Martineau. Martineau's slanted barrel and screen concept was further modified to a vertical barrel without a screen (Appendix E). Our change from a slanted to vertical orientation reduced operator fatigue associated with the old design. A small wooden frame fitted with a funnel and removable pint jar was used to support a tapered cylinder (a bottomless 20-gallon (76-liter) garbage can). Larvae were dislodged from the foliage within the cylinder and dropped down into the jar. Larvae or debris remaining in the barrel are brushed into the jar. Larvae were then separated and counted.

1981 Larval Development Sample

Larvae from initial development samples were removed by visual examination of the old foliage and buds. As new foliage began to flush, the beating barrel technique was initiated. Larvae removed by both methods were placed in 70 percent ethyl alcohol. Larvae were then separated by instar based on physical characteristics and head capsule size. Each day, instar data were tabulated and used to plan subsequent sampling and block releases.

1981 Prespray Sample

All prespray samples were processed using the beating barrel and then placed in 70 percent ethyl alcohol for counting. Larvae were divided into two categories: budworm and other foliage feeders. Number of new shoots per branch, branch length and branch width were also recorded.

1981 Spray Deposit Cards

Laboratory analysis of spray deposit cards was conducted by the Methods Application Group using a Quantimet® image analyzer located at the University of California, Davis, California. An automatic spot counting and sizing (ASCAS) computer program was used to summarize deposit data.

1981 Postspray Sample

Besides keeping a separate count of budworm and other larvae, postspray data were also tallied by pupae and empty pupal cases. Foliage examination was by the beating technique. The first two postspray samples (7- and 14-day) were saved for counting in alcohol. The final postspray (21-day) collection was live counted and placed in rearing dishes. When the Butte laboratory was closed, the rearing operation was moved to the CFPM laboratory in Missoula. Foliage feeding continued through pupation. A final tally and count wasn't made until most of the insects had emerged. Insects were then classified as follows:

Insect	Code
Budworm pupa	P
Budworm adult	A
Parasite pupa	PP
Parasite adult	PA
Other pupa	OP
Other adult	OA

1981 Egg Mass Sample

Foliage examination by longwave ultraviolet light was used to locate and remove budworm egg masses. Egg-bearing needles were pooled by branch in small petri dishes. Branch length and width were recorded. New and old masses were separated and counted. Up to two new egg masses per branch were measured to determine length and the number of rows.

1982 Larval Population Sample

Larvae were separated by instar based on physical characteristics and head capsule size.

1982 Rearing Sample

Feeding larvae were placed in petri dishes containing artificial media. All pupae were weighed and sexed to estimate fecundity. When all emergence had occurred, specimens were categorized as spruce budworm, other defoliator (due to mistakes in identifying budworm larvae or pupae in the field) or parasite; and whether the final stage reached was a larva, pupa, or adult. Parasite adults and puparia were identified using both published and unpublished keys.

1982 Egg Mass Sample

Branches were processed as described for the 1981 egg mass collection.

DATA ANALYSIS

Within each treatment, spray blocks were established as the basic sampling unit. Twenty-five observations, each a 3-tree cluster, were taken in each spray block. Means and standard errors were calculated

from the means of the 3-tree clusters. Analysis of variance and analysis of covariance were used to test for differences between treatments. Results are based primarily on covariance analysis (using the 1981 prespray populations as the covariate) in order to account for variations in pretreatment population levels. Student-Newman-Keuls tests were run to determine between which treatments differences occurred.

Parasite data for the 2 years sampled were analyzed separately due to inconsistencies in the collection methods used. Differences in percent parasitism (overall and by parasite species) were compared using analysis of variance and the Student-Newman-Keuls test of differences. It is assumed that parasite densities were consistent between blocks prior to spraying.

AIR OPERATIONS

Air operations were conducted out of the Butte airport, Butte, Montana. This location was within 13 air miles (21 air kilometers) of all but one of the spray blocks.

Contracting

Based on specifications provided by research and the B.t. task force, Region 1 prepared a solicitation package based on the following standards and Forest Service contracting regulations:

1. Minimum tank capacity - 350 gallons (1,325 liters)
2. Minimum production - 400 acres (162 hectares) per hour per aircraft
3. All aircraft same type and model
4. Volume median diameter droplet size - 150 to 200 microns (.59 to .79 inches)
5. Spray mixture recirculation capability
6. 125-foot (38-meter) minimum swath width when released 50 feet (15 meters) above canopy
7. Contract mixing and loading.

The contract award went to Arrow Aviation, Mountain Home, Idaho for two Ayers Turbo Thrush aircraft.

Spray Equipment

Each Turbo Thrush was equipped with Spraying Systems, Inc. fulljet one-eighth 66A8W spray tips 1.6 gallons per minute at 40 psi (6.1 liters per minute at 275,790 N/M^2) on #4666 check valves. Nozzles were mounted straight back on an air-foil type boom. To minimize wing tip vortices, nozzle placement was limited to the inboard three-fourths of each boom. Three nozzles were placed off center to compensate for the characteristic gap directly below the center of the aircraft.

Premixing was done in a 200-gallon (757-liter) batch tank with bypass recirculation. This unit was mounted on a 3,000-gallon (11,356-liter) tank truck.

Aircraft Calibration

Aircraft calibration was conducted over the main runway at the Butte airport. To achieve an equivalent flow rate of 1 gallon tank mix per acre (9.3 liters tank mix per hectare) at air speed of 140 mph (225 km/hr) with an assumed lane interval of 150 feet (46 meters), both aircraft were calibrated to deliver 42.4 gallons (160.5 liters) per minute at 40 psi (275,790 N/M^2).

Flow rate factors were calculated as follows:

$$\text{Flow rate factor} = 1/\sqrt{\text{specific gravity}}$$

Specific gravity — Dipel 4L = 0.974
Thuricide 16B = 1.118

Flow rate factor — Dipel 4L = 1.01
Thuricide 16B = 0.95.

To achieve the proper application rates, 26 nozzles were required for Dipel 4L and 28 nozzles for Thuricide 16B. Time trials were conducted with each aircraft to confirm this configuration. One aircraft checked out; the other required one additional spray tip for each tank mix.

Aircraft Characterization

Procedures described by Dumbauld and Rafferty were used to characterize deposition density over a test area. A test grid was established in a sagebrush flat approximately 10 air miles (16 air kilometers) from Butte airport. Sample points were placed at 10-foot (3-meter) intervals along a 460-foot (140-meter) north-south line. White Kromekote cards were placed at each point in plastic card holders. Grid center was marked with an orange fluorescent panel. Smoke grenades were used to guide the aircraft toward grid center.

On-site drop size determinations were made using the D-Max method. Tip orientation was changed as needed to bring droplet size within specifications. The following spread factor equations were used:

Dipel 4L — $Y = .69 + .53X$
Thuricide 16B — $Y = 5.22 + .30X$
Y = Aerodynamic drop size
X = Stain size

Mean drop density for 150-foot (46-meter) lane intervals were calculated using procedures described by Spillman. This technique determines cumulative deposit at a point when the deposition pattern from a single swath is overlapped at a specified lane interval. Mean and coefficient of variation were computed for 150-foot (46-meter) lane intervals. Full boom and three-fourths boom configurations were tested.

Ten trials were conducted over the test grid. Data from the first two were not computed because a polymirization of Acrylocoat caused a pump malfunction. The remaining eight characterization trials and actual spray applications were done without Acrylocoat. Appendix F summarizes these results. Volume median diameter (VMD) range for Dipel 4L was 119-152 microns (.047-.060 inches). This was below the 200 (.079) VMD specified. With nozzle orientation straight back and a larger orifice size unavailable we had no alternative but to accept the smaller drop size. The VMD range for Thuricide was 238 to 249 microns (.094 to .09 inches) (specified range 250-300 microns (.09 to .118 inches)). Deposit density (Appendix F) for all trials exceeded the specified density of 20 drops per cm^2 (129 drops per square inch). Thus, by using a 150-foot (46 – meter) lane interval, a deposition pattern within specificiations would be produced. The most uniform deposition profile was produced by the three-fourths boom configuration. Both aircraft were set up in this manner.

Application

All six applications were conducted from the Butte airport. The afternoon before a block was scheduled for spraying, both spray pilots were escorted by helicopter over the spray block by the aerial observer. That evening a final strategy session was held with the spray pilots to organize plans and resolve any problems identified. At dawn the following day, both aircraft were loaded and ready to go. Table 2 summarizes the number of acres sprayed, start and stop time, and application rate for each block.

Table 2. Acres sprayed, start and stop time, and application rate for spray blocks.

Block	Date	Size in acres (hectares)	Start	Stop	Total time	Application rate ac/hr/aircraft (hectares/hr per aircraft)
Grouse	June 29	2,400 (972)	5:53 a.m.	8:20 a.m.	2:27	490 (198)
Spire	June 30	3,650 (1,478)	5:20 a.m.	8:46 a.m.	3:36	531 (215)
Bald	July 1	2,000 (810)	7:06 a.m. 1/	9:04 a.m.	1:58	508 (206)
Whiskey	July 2	2,000 (810)	5:23 a.m.	7:25 a.m.	2:02	491 (199)
Coyote	July 3	2,500 (1,012)	5:27 a.m.	7:38 a.m.	2:11	572 (232)
Jimmie	July 5	4,200 (1,701)	5:05 a.m.	9:44 a.m.	4:39	451 (183)

1/ Delayed by early morning rain shower.

Pilots were assisted in boundary location, communications, etc. by an aerial observer. Spray deposit cards were reviewed with the pilots after each block. Problem areas were identified and corrective techniques were suggested.

Meteorology

Local weather forecasts and observations were provided by a meteorologist from the National Oceanic and Atmospheric Administration, satellite and other weather service information was available from a mobile fire weather unit set up at the laboratory. Daily forecasts were prepared for the project team briefing.

Weather recording equipment and observers were stationed within each block during application to monitor windspeed and direction, relative humidity, and temperature. The work plan specified spraying would stop when temperature was above 65°F (18°C) or winds exceeded 8 mph (13 km/hr). Appendix G summarizes weather conditions within each block recorded 6 feet (1.8 meters) above the ground. In four cases we went slightly beyond the 65°F (18°C) cutoff. In all blocks except one, wind conditions were well within specificiations. Even though spray conditions during treatment were generally excellent, there was very little additional time when conditions would have been suitable for treatment.

Communications

During application, communication was maintained between project personnel via two-way radio. Radio contact was available from the airport mixing and loading area to the meteorological monitoring site within the block, crew leaders, the observation helicopter, and the laboratory. Direct communications were not available from the loading area to the spray aircraft. Spray progress and meteorological conditions were available as needed by the project director. Spray pilots could be redirected by the aerial observer or while reloading. Pilot input during reloading was also helpful in controlling progress and monitoring meteorological changes.

ADMINISTRATION AND ORGANIZATION

Personnel from Cooperative Forestry and Pest Management, Region 1, in cooperation with the Deerlodge National Forest, Butte, Montana, conducted this project. Project organization is illustrated in Appendix H. The general organization was followed, except a spray strategist was added to give special assistance to the project director. Daily briefings were held each evening during the spray phase with key project and contract personnel. These meetings discussed and reviewed the following topics:

1. Larval development
2. Spray deposits for previous block
3. Meteorological conditions for previous block
4. Weather forecast
5. Block boundaries and topography
6. Safety
7. Application strategy
8. Deposit crew assignments

Representatives from Abbott Laboratories and Sandoz, Inc. were available throughout the spray phase for technical assistance on mixing and application.

SAFETY

A project safety plan and aircraft operations plan were prepared for this project. Additional guidance was found in Forest Service directives (FSM 6700, FSH 6709.11) and FPM Unit Safety Plan. Temporary field and laboratory crew members received appropriate safety and driver safety orientation. The results of our safety efforts were manifest by an excellent record of aircraft, vehicle, and crew-related activities. A minor accident occurred while backing a vehicle, resulting in minor damage to the right rear side panel. Project activities are summarized below:

Personnel		
Permanent	3,410	hours
Field crew	2,850	hours
Laboratory crew	4,555	hours
Total	10,715	
Vehicles		
Miles driven	27,500	
Aircraft		
Spraying	34 hours or 16,750	acres
Observation	38	hours

INFORM AND INVOLVE

The Forest Supervisor's office provided direction and coordination for the information phase of the project. Information functions were designed to insure that key individuals and the general public were informed about this project. Specific emphasis was given on the significance and safety of B.t. in Integrated Pest Management (IPM). An Inform and Involve Plan was prepared which called for the following actions:

1. Contact community leaders
2. Announce project schedule
3. B.t. fact sheet
4. Describe local budworm situation
5. An open house
6. News releases

BUDGET SUMMARY

This project was financed through special project funding provided by the Chief's office, Forest Pest Management, and was administered by Cooperative Forestry and Pest Management personnel in Missoula, Montana. Appendix I summarizes actual expenditures by budget item. Included are dollar amounts for contributed pesticides, equipment, vehicle use, salaries, and laboratory space. Contributions came from various Forest Service units and from the local community. These contributions added greatly to the efficiency of the project in terms of dollars spent and personnel needs.

ASSOCIATED STUDIES

In addition to the primary project design and objectives, several other activities were conducted in conjunction with this project. This project gave other investigators an excellent opportunity to collect data in different phases of aerial application.

The Canada-United States spruce budworms program (CANUSA) funded a study to determine optimum spray timing for B.t. applications. Principal investigator was Dan Twardus, Forest Pest Management, Portland, Oregon. The Method Applications Group, Fort Collins, Colorado, supported an evaluation using Douglas-fir needles as a medium for spray deposit assessment, principal investigator was William Ciesla. Robert Ekblad, Missoula Equipment and Development Center, used a new drift sampler to monitor drift. Hank Thompson checked both early and late instar larvae for traces of B.t. during 1982. There was no evidence that B.t. had been passed from the sprayed population to the following generation of larvae. Richard Reardon from the Pacific Southwest Forest and Range Experiment Station made imprints from old foliage to determine if B.t. was present the year following spraying. These studies will be reported separately.

RESULTS AND DISCUSSION

1981 Larval Development

Each block was scheduled for treatment when 50 percent of the larval population were in instars four, five, and six. Blocks were released as follows:

Block	Release date	Larvae in instar 4,5,6 (percent)	Treatment date
Grouse	June 27	67	June 29
Spire	June 27	77	June 30
Coyote	June 27	49	July 3
Bald	June 27	67	July 1
Whiskey	June 28	60	July 2
Fish	June 30	47	Control
Divide	June 30	43	Control
Jerry	July 2	45	Control
Jimmie	July 2	70	July 5

Because delays in treatment would occur, and to save further development samples, some blocks were released below the 50 percent level. Prespray development data confirmed these projections (Table 3).

Table 3. Prespray larval distribution by instar (percent).

Prespray instar	Block					
	Grouse	Spire	Coyote	Whiskey	Bald	Jimmie
2	2.5	1.0	0.7	1.2	0	10.6
3	21.8	21.0	10.7	10.7	4.0	15.6
4	17.5	25.3	28.5	28.5	19.0	36.4
5	56.3	48.0	47.2	47.2	64.0	35.2
6	1.8	4.8	12.5	12.5	13.0	2.2
Prespray 4,5,6	75.6	78.1	89.2	88.2	96.0	73.8
Development 4,5,6	67.0	77.0	49.0	60.0	67.0	70.0
Increase %	8.6	1.1	40.2	28.2	29.0	3.8
Delay (days)	1	2	5	3	3	2

For several blocks the increase between development and prespray was larger than we expected thus putting development in some blocks well beyond the 50 percent threshold. These differences (delays) may seem long but bud development information collected by Dan Twardus points out that bud expansion at treatment was less than optimum (Table 4).

Table 4. Bud development during prespray sample.

Bud condition	Block					
	Grouse	Spire	Coyote	Whiskey	Bald	Jimmie
Fully expanded (percent)	52.6	75.6	78.7	76.8	77.0	62.4
None or partially expanded (percent)	47.5	24.4	21.3	23.2	23.0	37.6

His data indicated that an even later timing would have been better. Small larvae protected within these buds were probably never exposed to the treatment while those larvae on expanded buds received the applied dose. Thus, the treatment had a disproportionate effect on the more exposed large larvae. This condition was manifest in the 21-day sample with a larger proportion (percent) of pupae in the control blocks (Table 5).

Table 5. Percent pupae in 21-day samples.

Dipel		Thuricide		Control	
Grouse	11	Spire	13	Fish	47
Bald	26	Coyote	15	Divide	55
Jimmie	5	Whiskey	18	Jerry	30
Mean	14	Mean	15	Mean	44

Small larvae which survived in tight or partially opened buds could partially account for this difference. The larger exposed larvae in the control blocks were not lost, thus many reached pupation before the 21-day sample.

1981 Prespray Population Densities

Since other species of bud feeding larvae made up nearly half of many samples, population data were analyzed and summarized in three groups: (1) western spruce budworm, (2) nonbudworm (other), and (3) total larvae. Prespray densities by block sampling period and treatment are summarized in Appendices J1 to J3.

Analyses of variance on prespray larval densities for budworm, other, and combined all failed to show significant differences between treatments (Appendix K).

Prespray densities were used as covariates in our analyses to account for variation between blocks prior to treatment.

1981 Spray Deposit

Spray deposit data were analyzed using the ASCAS computer program. This analysis is summarized by block in Appendix L. Droplet size for Thuricide was below the 250-300 um (.098-.118 inch) range specified by the work plan while Dipel drops were a little larger than the 200 um (.079 inch) target. In either case, droplet size was acceptable. Deposit density was very consistent except in the Bald block. Drops per square centimeter in Bald were less than half that recorded in the other blocks. This block was treated following the passage of a weak cold front and before conditions had stabilized (Appendix G). Overall deposit density was uniform within blocks.

1981 Population Reduction

Analysis of covariance showed treatment differences in all postspray larval density samples except one (Appendices M1 to M3). In each case the Thuricide treatment was significantly lower than the control blocks. Population densities in Dipel areas were always intermediate; containing statistically fewer larvae than check areas in all collections except the 7-day combined. No significant differences between Dipel and Thuricide were found in any of the samples.

Analysis of covariance and Abbott's formula were used to determine adjusted mortality and to provide a common comparison between this and other projects (Appendix N). Adjusted combined population reductions at 21 days were 37 and 60 percent for Dipel and Thuricide, respectively, using analysis of covariance; and 43 and 59 percent for Dipel and Thuricide using Abbott's formula. However, a direct comparison at 21 days is not proper for a biological agent of this type.

1981 Rearing

Larvae and pupae of all bud feeders, (combined) from the 21-day sample were placed in petri dishes and allowed to continue development. Survival rates by block and treatment are reported in Table 6.

Table 6. Percent survival of all defoliators in the 21-day postspray collection.

Dipel		Thuricide		Control	
Block	Surviving	Block	Surviving	Block	Surviving
Grouse	20.4	Spire	13.9	Fish	53.8
Bald	18.8	Coyote	20.5	Divide	56.7
Jimmie	27.8	Whiskey	12.7	Jerry	50.3
Mean	22.3	Mean	15.4	Mean	53.6

These differential rates of survival represent treatment effects beyond the 21-day sample.

For the combined population a residual density per 100 shoots is obtained by adjusting the 21-day population by percent survival for that sample (Table 7). This calculated density represents insect densities prior to the egg stage.

Table 7. Calculated residual population of all defoliators.

Treatment/ Block	21-day population (larvae/100 shoots)[1/]	Rearing survival (percent)	Calculated residual population/100 shoots
Dipel			
Grouse	4.57	20.4	.93
Bald	6.95	18.8	1.31
Jimmie	6.50	27.8	1.81
Mean	6.01	22.3	1.35
Thuricide			
Spire	5.20	13.1	.68
Coyote	6.54	20.5	1.34
Whiskey	3.41	12.7	.43
Mean	5.05	15.4	.82
Control			
Fish	6.42	53.8	3.45
Divide	17.08	56.7	9.68
Jerry	11.24	50.3	5.65
Mean	11.58	53.6	6.26

1/ Taken from Appendix J3.

Rearing survival was significantly different between control and both B.t. formulations but not between Dipel and Thuricide (Appendix O). By analysis of covariance, the residual population means adjusted for prespray differences were significantly different at the 99 percent level, with the Dipel and Thuricide blocks statistically lower than the check areas (Appendix O). Adjusted population reductions for Dipel and Thuricide were 79 and 91 percent, respectively. Though evaluations of conventional insecticides are commonly conducted at 21-days postspray, B.t. shows treatment effects beyond this time. Therefore, later samples will have to be conducted to fully evaluate the impact of B.t. on residual population levels.

Average percent parasitism was summarized for blocks and treatments (Table 8).

Table 8. Percent parasitism of all defoliators in the 21-day postspray collection.

Dipel		Thuricide		Control	
Grouse	20.3	Spire	16.8	Fish	26.3
Bald	17.4	Coyote	21.7	Divide	24.0
Jimmie	26.8	Whiskey	21.0	Jerry	27.7
Mean	21.5	Mean	19.8	Mean	26.0

Percent parasitism was not significantly different between treatments (Appendix P). This analysis included parasites of all defoliator species, as spruce budworm were not separated in this collection. Due to the high number of nonbudworm larvae present in the test areas (averaging 37 percent), any effects of B.t. on spruce budworm populations would be very difficult to discern.

1981 Defoliation Assessment

Following pupation, defoliation estimates were recorded for each cluster tree in all blocks. Defoliation averages by block and treatment are reported in Table 9.

Table 9. Percent defoliation in 1981.

Dipel		Thuricide		Control	
Block	Defoliation	Block	Defoliation	Block	Defoliation
Grouse	23.0	Spire	38.2	Fish	24.5
Bald	37.4	Coyote	40.2	Divide	57.7
Jimmie	29.0	Whiskey	32.3	Jerry	58.8
Mean	29.8	Mean	36.9	Mean	47.0

Both the Dipel and Thuricide treatments showed significantly less defoliation than did the control blocks (Appendix Q). In contrast to the postspray population densities, Dipel showed a lower mean defoliation level than did the Thuricide areas.

1981 Egg Density

Two of the four branches used to estimate defoliation were retained for egg mass examination. Egg mass density (number of masses per square meter (foot) of foliage) and the number of eggs (per square meter (foot)) are summarized by block and treatment in Table 10.

Table 10. Average egg mass density and number of eggs in 1981.

Treatment/ block	Egg mass density masses/sq. meter (masses/sq. foot)	Number of eggs eggs/sq. meter (eggs/sq. foot)
Dipel		
Grouse	12.9 (3.9)	439.8 (134.1)
Jimmie	12.2 (3.7)	326.3 (99.5)
Mean	18.3 (5.6)	583.0 (177.7)
Thuricide		
Spire	21.0 (6.4)	740.0 (225.6)
Coyote	15.4 (4.7)	499.5 (152.5)
Whiskey	16.4 (5.0)	492.6 (150.1)
Mean	17.6 (5.4)	577.4 (176.0)
Control		
Fish	21.8 (6.6)	795.8 (242.6)
Divide	64.1 (19.5)	3343.9 (1019.2)
Jerry	29.7 (9.1)	985.9 (300.5)
Mean	38.5 (11.7)	1708.5 (520.8)

Using prespray larval population density as a covariant, neither egg mass density nor number of eggs showed differences between treatments (Appendix R).

1981 Treatment Cost

Treatment cost was calculated on the basis of application, insecticide, and dye. Application rate averaged $7.63 per acre ($18.84 per hectare). Aerial application costs were $2.14 per acre ($5.28 per hectare); the balance, $5.49 per acre ($13.56 per hectare) was for materials (B.t. and dye). For an operational control program over large areas, the unit cost per acre would be less. The biggest savings would result from using larger spray aircraft.

1981 Efficacy

An objective of this project is to compare these results with those of its sister project in New Mexico. The following is a comparison of 21-day adjusted budworm mortality (Abbott's formula) by material and area:

Area	Dipel	Thuricide
Montana	30 percent	48 percent
New Mexico	50 percent	70 percent

Additional comparison can be made using other data from this report and the project report from New Mexico.

1982 Larval Population Density

Larval densities for budworm, other, and combined are listed by block and treatment in Table 11.

Table 11. Larval densities for spruce budworm, other, and combined in 1982.

Treatment/ block	Larvae per 100 shoots		
	Budworm	Other	Combined
Dipel			
Grouse	3.1	2.9	5.2
Bald	5.4	4.0	7.9
Jimmie	4.7	2.4	6.1
Mean	4.4	3.1	6.4
Thuricide			
Spire	3.7	4.5	7.2
Coyote	3.8	4.5	7.2
Whiskey	3.0	3.1	5.3
Mean	3.5	4.0	6.6
Control			
Fish	5.6	5.5	9.4
Divide	22.8	11.0	27.6
Jerry	9.6	3.7	11.0
Mean	12.7	6.7	16.0

Covariance analysis showed no differences in the number of spruce budworm larvae between treatments the year following spraying (Appendix S). Both the Thuricide and Dipel blocks had significantly lower densities of nonbudworm larvae than did the control areas. Due to the preponderance of nonbudworm in the sample, the combined larvae count also showed statistically fewer insects in the sprayed areas.

These data are consistent with the 1981 egg density information which also showed no differences in budworm population levels due to treatment effects.

1982 Rearing

The percent of female spruce budworm emerging as adults and their weight as pupae were recorded as indications of potential fecundity (Table 12).

Table 12. Percent female pupae, percent female adults, and average weight of female pupae reared in 1982.

Treatment/ block	% female pupae	% female adults	Wt. of female pupae in mg. (grains)
Dipel			
Grouse	64.0	64.8	115.1 (1.78)
Bald	60.4	60.6	118.1 (1.82)
Jimmie	55.5	58.7	130.6 (2.02)
Mean	60.0	61.4	121.3 (1.87)
Thuricide			
Spire	59.6	61.1	122.1 (1.88)
Coyote	52.2	55.8	120.8 (1.86)
Whiskey	66.0	69.0	98.8 (1.52)
Mean	59.3	62.0	113.9 (1.76)
Control			
Fish	47.6	52.0	135.3 (2.09)
Divide	45.1	51.3	128.2 (1.98)
Jerry	49.5	53.8	115.3 (1.78)
Mean	49.5	52.4	126.3 (1.95)

Analysis of variance showed that both the Dipel and Thuricide treatments had a greater proportion of females than did the controls; however, there was no difference in pupal weights due to treatment (Appendix T). This information implies that the sprayed blocks have a greater potential for egg production than do the check areas.

The percent of female pupae collected was also recorded (Table 12) in order to determine if hosts are differentially parasitized due to their sex. Analysis of variance showed a significantly higher proportion of females in treated plots than in controls (Appendix T). This relationship is maintained in the emerging budworm adults; therefore, it appears that sex is not a factor in host selection by budworm parasites.

Information from the early and late parasite collections in 1982 were combined for analysis in order to give a better representation of the entire spruce budworm parasite complex (Table 13). Percent parasitism in the check blocks was intermediate, with the Thuricide treatment having the highest parasitism rate and Dipel the lowest (Appendix U).

Table 13. Percent parasitism of spruce budworm in 1982.

Dipel		Thuricide		Control	
Block	% parasitism	Block	% parasitism	Block	% parasitism
Grouse	4.0	Spire	7.2	Fish	7.2
Bald	4.5	Coyote	9.8	Divide	5.4
Jimmie	6.7	Whiskey	8.8	Jerry	9.1
Mean	5.1	Mean	8.6	Mean	7.3

The five most common parasite species were analyzed individually to determine their relative abundance in control and spray blocks (Appendix V). The braconids, *Apanteles* spp. and the ichneumonid, *Glypta fumiferanae* (Vier.) oviposit in prediapausing first instar larvae, while the ichneumonid, *Phaeogenes hariolus* (Cr.) and the tachinids, *Cermoasia auricaudata* Tns. and *Madremyia saundersii* (Will.) attack late instar larvae and pupae. *A.* spp. were significantly more abundant in the Thuricide treated areas than in either the Dipel or control blocks. *G. fumiferanae* showed no differences between treatments. Parasitism by *P. hariolus* was greatest in Thuricide blocks, intermediate in check blocks, and lowest in areas sprayed with Dipel. Both tachinids were significantly more abundant in control blocks.

Previous studies indicate that application of B.t. may affect the composition of the parasite complex indirectly, due to host response to the insecticide. Parasites attacking prediapausing larvae cause a photo negative response and reduce feeding sharply, thus larvae are less likely to come in contact with the spray. Our study results are inconclusive; though the Thuricide treatment contained the highest percentage of *A.* spp., *G. fumiferanae,* (which was the most abundant species reared), showed no differences between treatments. Parasitism of late instar larvae and pupae is believed to drop after application of B.t. due to reduction of the host population. Both tachinid species were significantly more abundant in check areas as would be expected; however, the number of specimens collected was relatively few. *P. hariolus,* which was the most common late instar or pupal parasite recovered, was most numerous in the Thuricide blocks, intermediate in checks, and lowest in the Dipel sprayed areas. Again, the parasite complex does not appear to reflect changes due to the spray project.

1982 Defoliation Assessment

Mean percent defoliation is listed by block and treatment in Table 14.

Table 14. Percent defoliation in 1982.

Dipel		Thuricide		Control	
Block	Defoliation	Block	Defoliation	Block	Defoliation
Grouse	23.2	Spire	31.1	Fish	48.4
Bald	30.8	Coyote	31.8	Divide	85.6
Jimmie	32.6	Whiskey	24.6	Jerry	69.3
Mean	28.9	Mean	29.2	Mean	67.8

Both the Thuricide and Dipel treatments showed significantly lower defoliation levels than did the controls (Appendix W).

1982 Egg Density

Egg mass density (masses/square meter (foot)) and mean number of eggs (per square meter (foot)) by treatment and block are reported in Table 15.

Table 15. Average egg mass density and number of eggs in 1982.

Treatment/ block	Egg mass density masses/sq. meter (masses/sq. foot)	Number of eggs eggs/sq. meter (eggs/sq. foot)
Dipel		
Grouse	24.4 (7.4)	1124.1 (342.6)
Bald	65.3 (19.9)	3133.4 (955.1)
Jimmie	43.9 (13.4)	2103.7 (641.2)
Mean	44.5 (13.6)	2120.4 (646.3)
Thuricide		
Spire	37.8 (11.5)	1881.4 (573.5)
Coyote	45.0 (13.7)	2307.3 (703.3)
Whiskey	36.3 (11.1)	1689.2 (514.9)
Mean	39.7 (12.1)	1959.3 (597.2)
Control		
Fish	76.2 (23.2)	4254.9 (1296.9)
Divide	113.1 (34.5)	6540.0 (1993.4)
Jerry	46.4 (14.1)	2328.6 (709.8)
Mean	78.6 (24.0)	4374.5 (1333.3)

Neither the egg mass density nor the number of individual eggs was significantly different between treatment and control blocks (Appendix X). This is consistent with the 1981 data which also showed the distribution of eggs to be similar in all areas.

CONCLUSIONS AND RECOMMENDATIONS

These recommendations are based on the results and analyses from the first and second years' data.

Future Use of B.t.

The adjusted mortality after pupation was below the 95 percent range we commonly achieve with conventional insecticides. However, B.t. at 8 BIU per acre (19.8 BIU per hectare) would be an effective treatment when used in conjunction with operational projects using conventional insecticides. B.t. could be used along streams, in buffer strips and where other pesticides have been restricted.

Spray Strategist

The spray strategist provided effective communication between the spray pilot and project director. Data collected and summarized by the spray strategist provided a timely and positive feedback to the spray pilots on application and spray deposit. The spray strategist also provided on-site meteorological data monitoring during application.

Application Timing

We sprayed when a large portion of the budworm population was small and from 20 to 47 percent of the buds were not fully expanded. A later timing would allow both the insects and the buds to develop further, thus putting a much larger portion of the population in a more exposed and free-feeding position. Large blocks in steep terrain may need to be stratified by elevation to reduce the variation in bud expansion throughout a block.

Batch Mixing

Small batch mixing eliminated the storage problem and the potential for discarding large quantities of tank mix usually associated with mixing large quantities. Environmental concerns would be greatly reduced and pesticide orders could be limited to actual needs with this method of mixing.

Pesticide Containers

No mixing or treating delays were encountered while using small containers (2½ to 5 gallons (9.5 to 19 liters)). They did present a minor disposal problem. Better mixing efficiency and greater capacity are possible using a metered hand pump on large drums.

Data Forms

Field and laboratory data were transferred to a common data form designed with column numbers for data entry. Hand transcription was slow and prone to error. To improve efficiency and reduce errors, a single form could be designed for field use, for later use in the laboratory, and finally for data entry to the computer. A single form would reduce overhead and insure all entries were complete and legible.

REFERENCES

Abbott Laboratories.
1978. Dipel Technical Manual. Abbott Laboratories, 34 p.

Abbott, W. S.
1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 255-267.

Barry, J. W., R. B. Ekblad, G. P. Markin, and G. C. Trostle.
1978. Methods of sampling and accessing deposits of insecticidal sprays released over forests. USDA For. Ser., Davis, CA. Tech. Bull. 1596, 162 p.

Barry J. W., G. P. Markin, and R. B. Ekblad.
1977. Sampling and assessing deposition of insecticide sprays released over forests. USDA For. Ser., Davis, CA, Hndbk. (draft), 135 p.

Bullard, A. T. and R. W. young.
1980. Prediction of western spruce budworm defoliation on Douglas-fir. USDA For. Ser., Davis, CA, Rpt. 80-10, 52 p.

Coppell, H. C.
1960. Key to adults of dipterous parasites of spruce budworm, *Choristoneura fumiferana* (Clem.) (Lepitoptera: Tortricidae). Ann. Entomol. Soc. Am. 53: 94-97.

DeBoo, R. F., L. M. Campbell, and A. G. Copeman.
1973. A sampling technique for estimating numerical trends in larval populations of insect defoliators on conifers. I. Development and experimental evaluation of the technique. Phytoprotection 54(1): 9-22.

Dumbauld, R. K. and J. E. Rafferty.
1977. Field manual for characterizing spray from small aircraft. USDA For. Ser., Missoula, MT, Rpt. TR-76-113-01, 68 p.

Fellin, D. G., and J. E. Dewey
1982. Western spruce budworm. USDA For. Ser., For. Pest Leafl. 53, 10 p.

Flavell, T. H., S. Tunnock, and H. E. Meyer.
1976. A pilot project evaluating trichlorofon and acephate for managing the western spruce budworm, *Choristoneura occidentalis* Freeman, Helena National Forest, Montana, 1976. USDA For. Ser., Missoula, MT, Rpt. 77-15, 49 p.

Grimble, D. G. and R. W. Young.
1977. Western spruce budworm egg mass defoliation surveys, a working group progress report. USDA For. Ser., Davis, CA, Rpt. 77-3, 21 p.

Hamel, D. R.
1977. The effects of *Bacillus thuringiensis* on parasitoids of the western spruce budworm, *Choristoneura occidentalis* (Lepidoptera: Tortricidae), and the spruce coneworm, *Dioryctria reniculelloides* (Lepidoptera: Pyralidae), in Montana. Can. Entomol. 109: 1409-1415.

Hamel, D. R.
1981. Forest management chemicals, a guide to use when considering pesticides for forest management. USDA Agr. Hndbk. 585, 512 p.

Harper, J. D.
1974. Forest insect control with *Bacillus thuringiensis* - Survey of current knowledge. Agr. Exp. Sta., Auburn, AL, 64 p.

Jennings, D. T., and M. W. Houseweart.
1978. Sexing spruce budworm pupae. USDA For. ser., For. Ser. Res. Not. NE-255, 2 p.

Knopf, J. A. E., G. P. Markin, P. J. Shea, and W. M. Ciesla.
1979. Western spruce budworm population densities and defoliation one year after insecticide treatment of small blocks. USDA For. Ser., Method Applications Group, Davis, CA, Rpt. 80-1, 13 p.

Maksymiuk, B.
1963. How to estimate the atomization of oil-base sprays by the D-Max Method. USDA For. Ser., Res. Note WO-1, 6 p.

Maksymiuk, B.
1979. Microbial control of defoliators. In: Forest Insect Survey and Control. J. A. Rudinsky ed., Oregon State University, Corvallis, OR, pp. 135-171.

Markin, G. P.
1982. Abundance and life cycle of Lepidoptera associated with an outbreak of the western spruce budworm, *Choristoneura occidentalis*, (Lepidoptera: Tortricidae) in southeastern Idaho. J. Can. Ent. Soc. 55(2): 365-372.

Markin, G. P., C. Horning, and L. E. Stipe.
(In preparation) Effect of Bacillus thuringiensis on associated Lepidoptera during a western spruce budworm pilot control program. J. Can. Ent. Soc.

Martineau, R. M., and P. Benoit.
1973. A sampling technique for estimating numerical trend in larval populations of insect defoliators on conifers. II. Modification and operational use of the technique for extensive sampling of spruce budworm populations in Quebec. Phytoprotection 54(1): 23-31.

Ross, D. A.
1952. Key to the puparia of the dipterous parasites of Choristoneura fumiferana Clem. Can. Entomol. 84: 108-112.

Sandoz, Inc.
1980. Product Bulletin, Thuricide biological insecticide. Sandoz, Inc., 3 p.

Spillman, J. J.
1980. The efficiency of aerial spraying. Aeronautical J. of the Royal Aeronautical Soc., Feb.: 60-69.

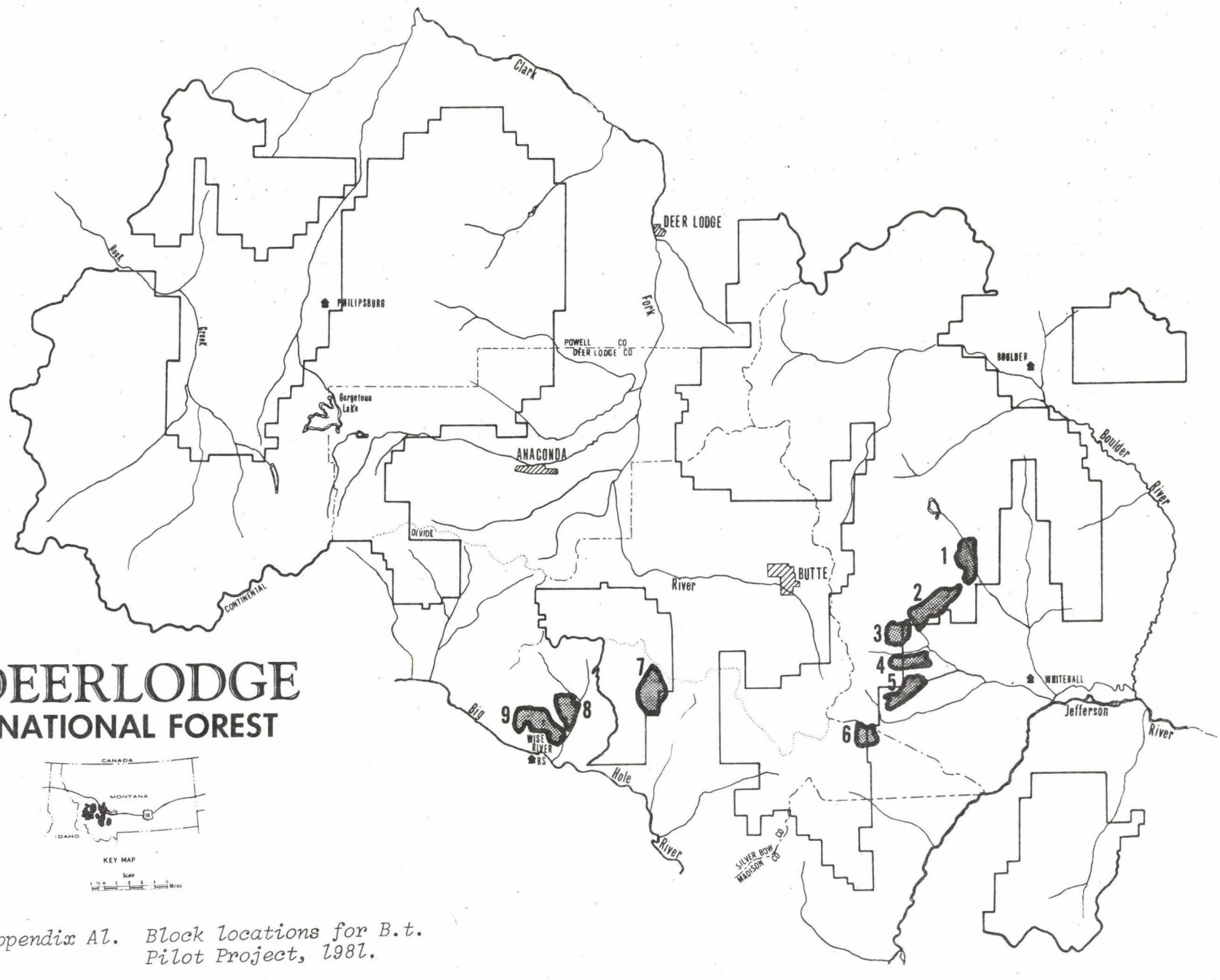
Steel, R. G. D., and J. H. Torrie.
1960. Principles and procedures of statistics. McGraw-Hill. New York, Toronto, and London, 481 p.

Stipe, L. E., J. A. E. Knopf, R. L. Livingston, R. W. Young, and G. P. Markin.
1977. A pilot project with Orthene® for control of the western spruce budworm, McCall, ID, 1977. USDA For. Ser., Ogden, UT, 34 p.

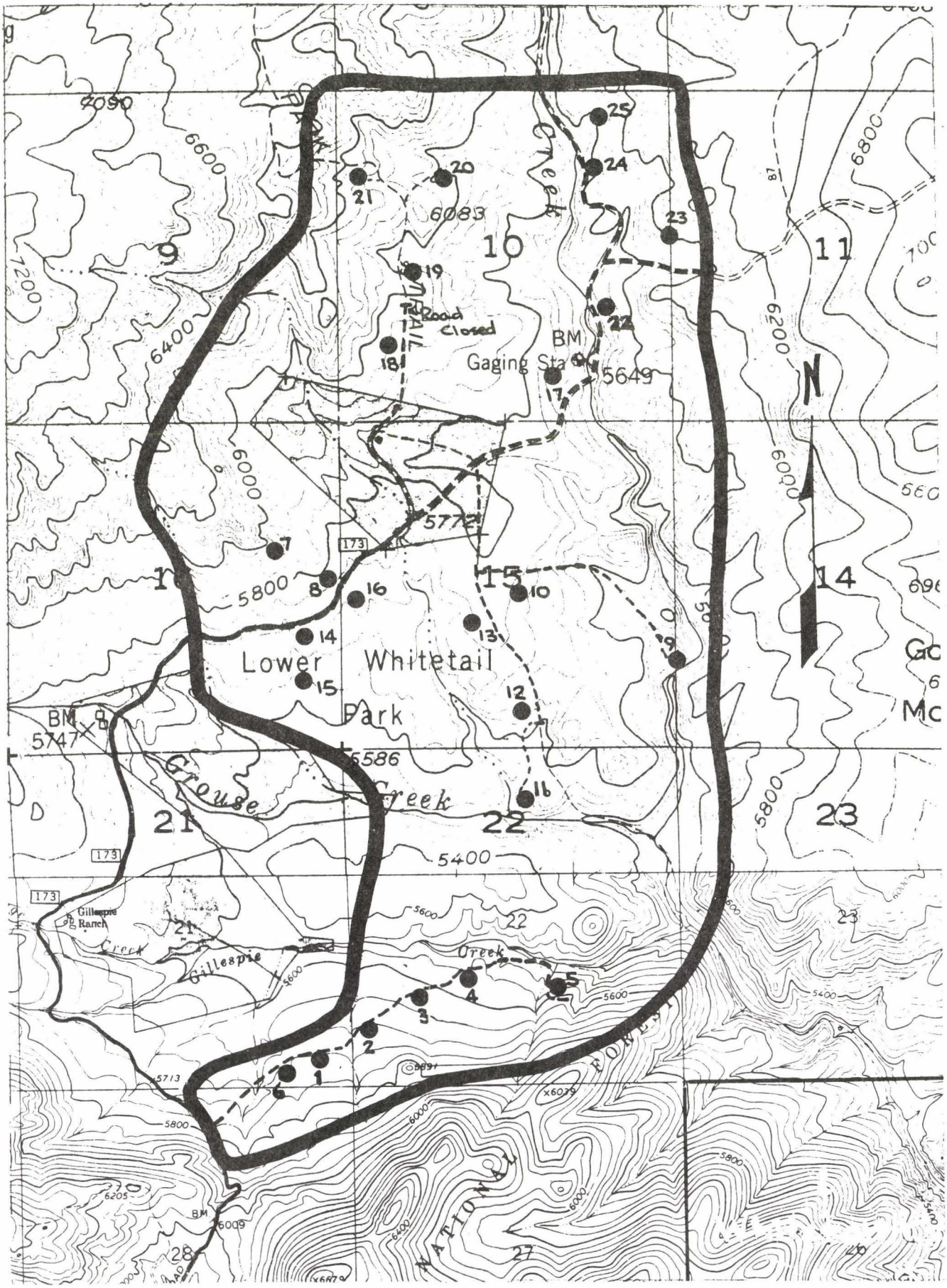
Wilson, L. F. and J. L. Bean.
1962. A field key to the adult hymenopterus parasites of the spruce budworm in Minnesota. USDA For. Ser., Lake States For. Exp. Sta., Res. Note LS-53, 4 p.

Young, R. W., R. C. Luebbe, and J. W. Barry.
1977. ASCAS data management system for assessment of aerial spray deposits. Methods Application Group, FI&DM, USDA For. Ser., Davis, CA, Rpt. 77-2, 29 p.

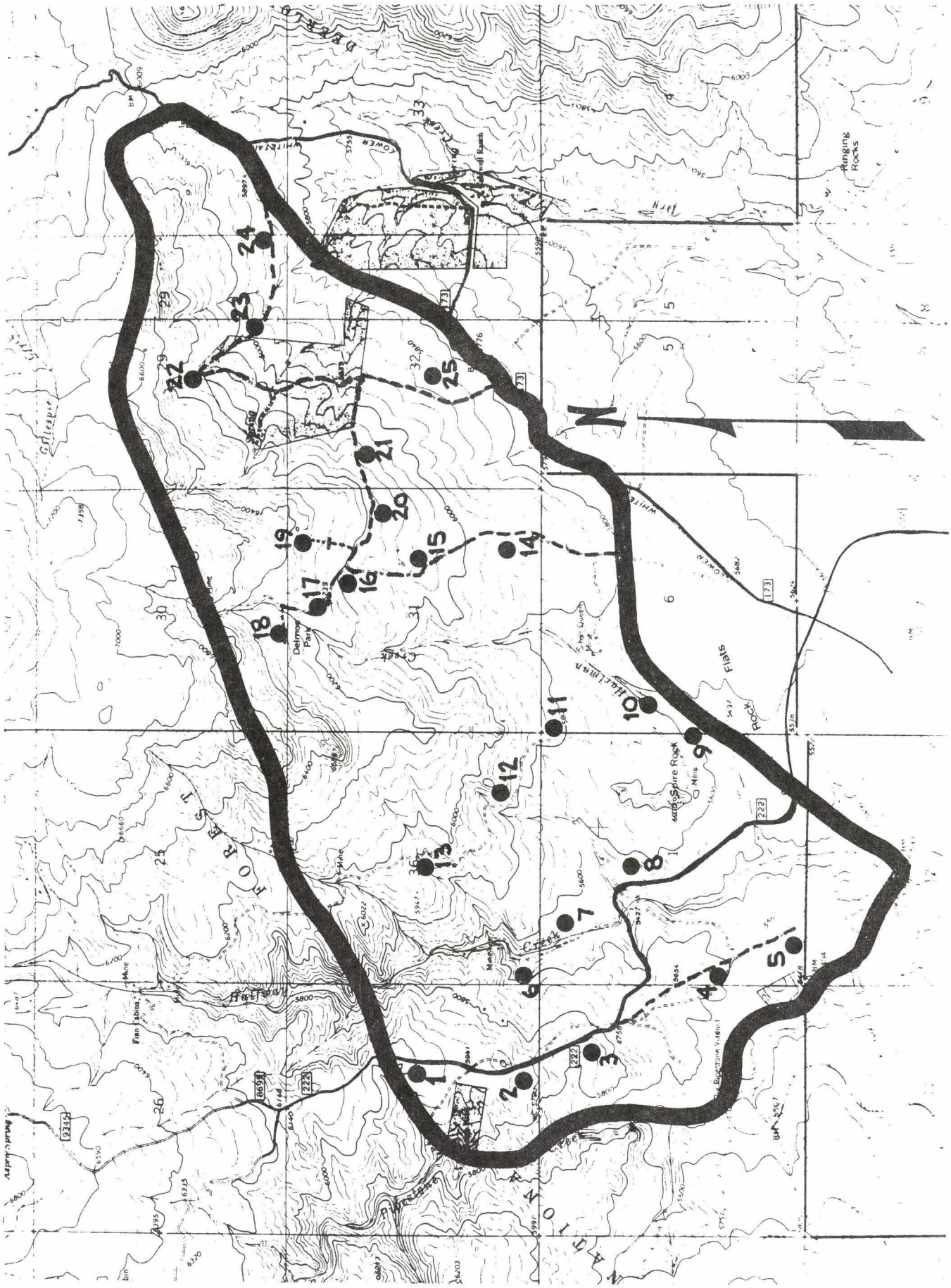
APPENDICES



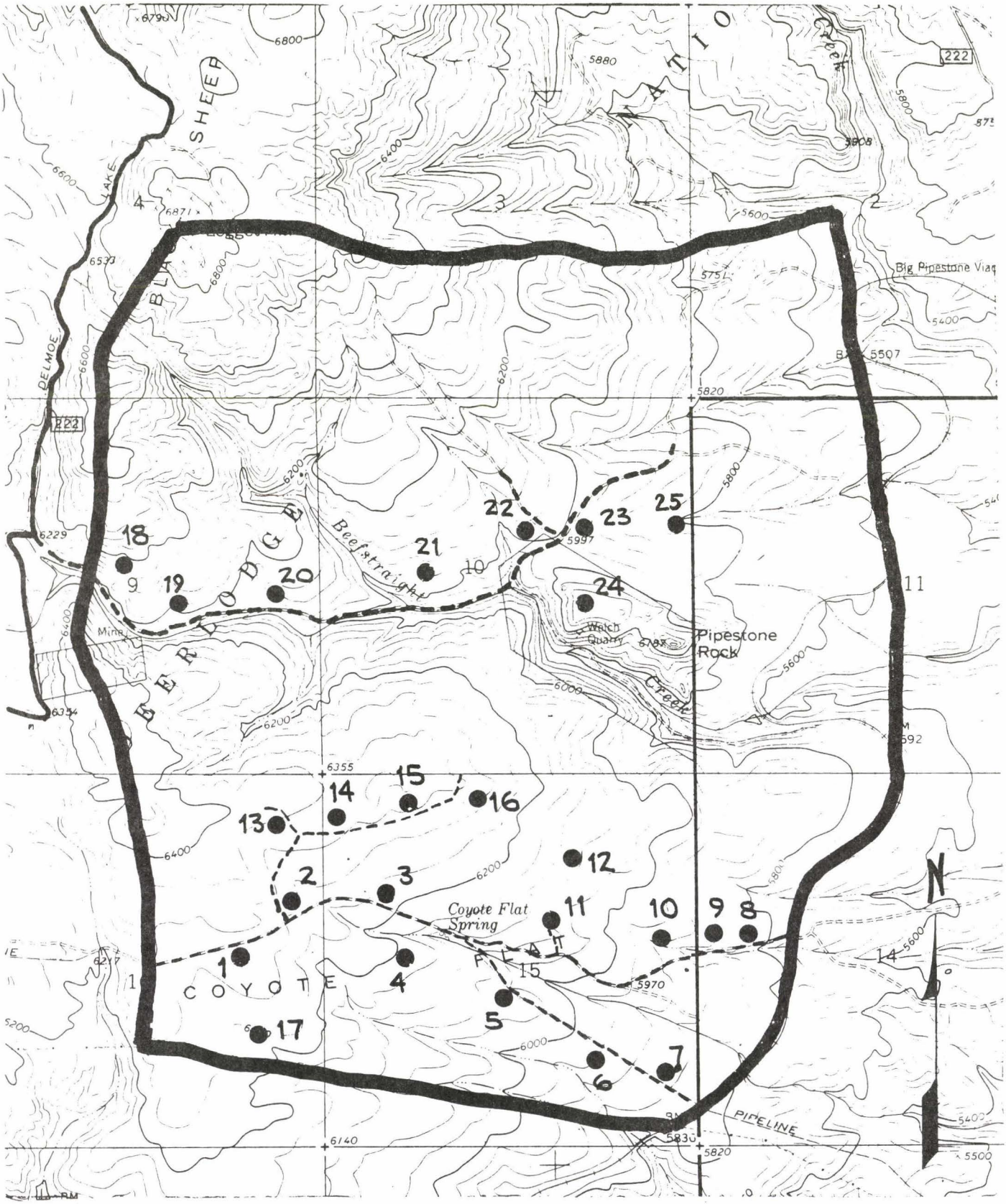
Appendix A1. Block locations for B.t. Pilot Project, 1981.



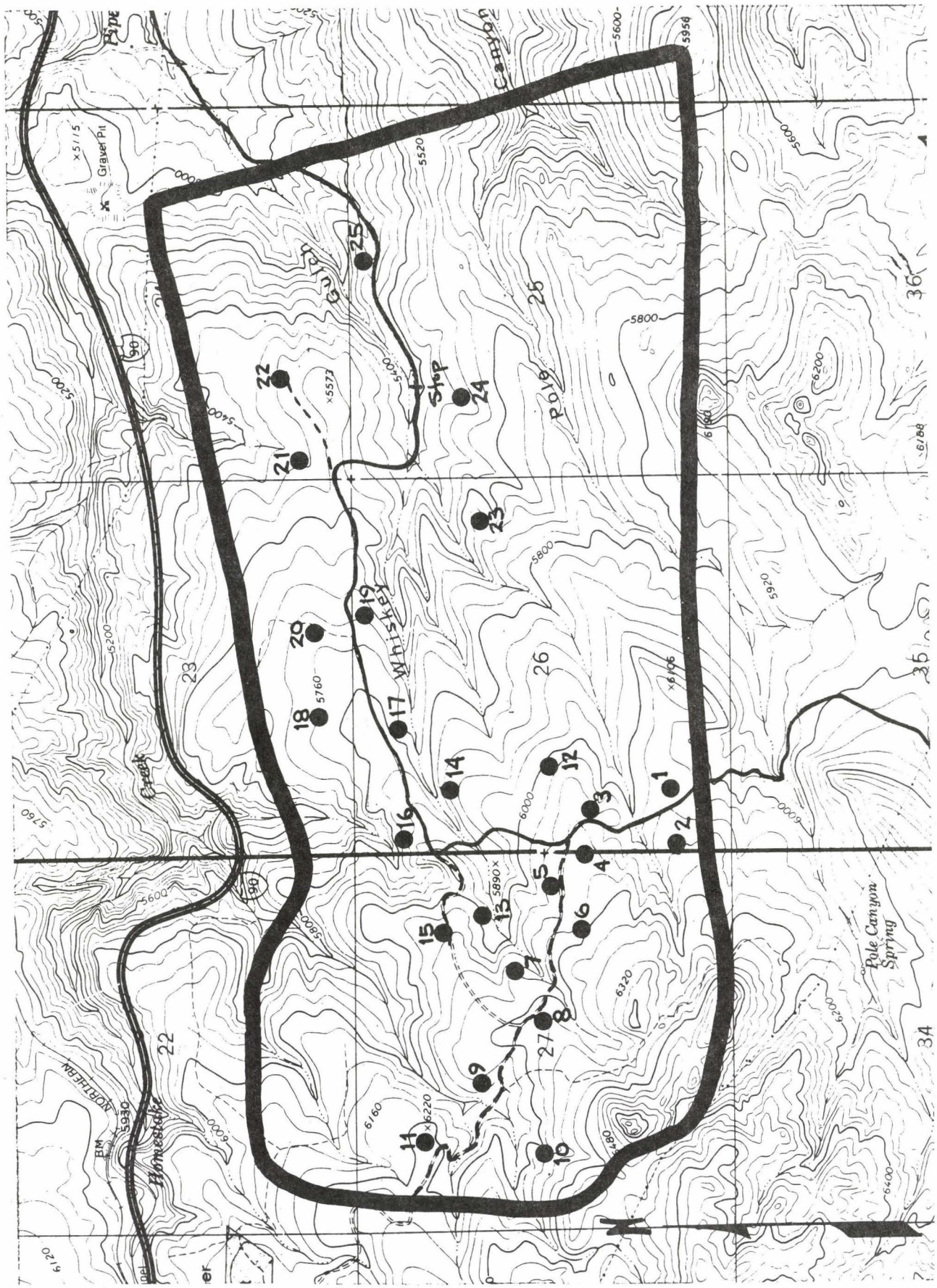
Appendix A2. Cluster locations - Grouse.



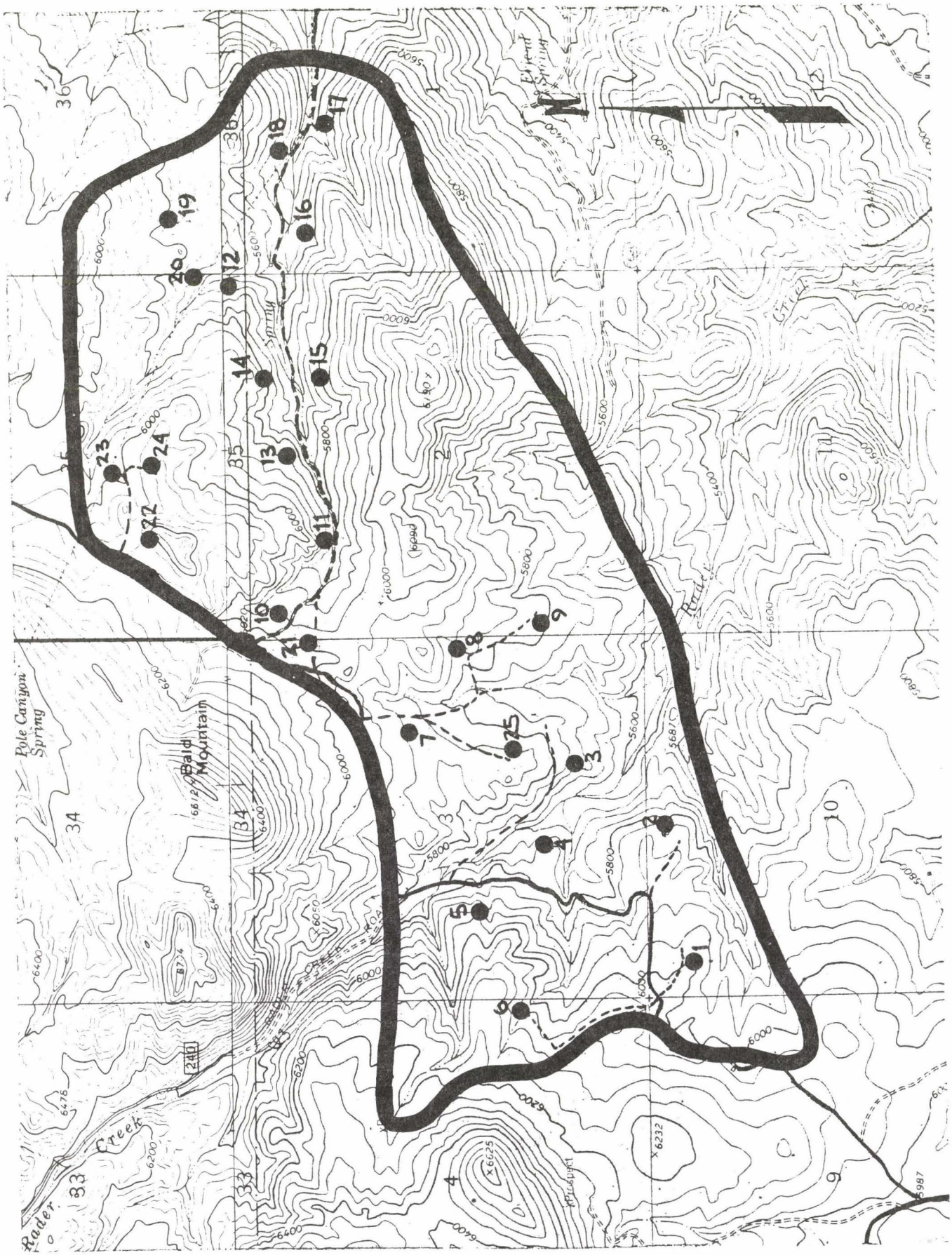
Appendix A3. Cluster locations - Spire.



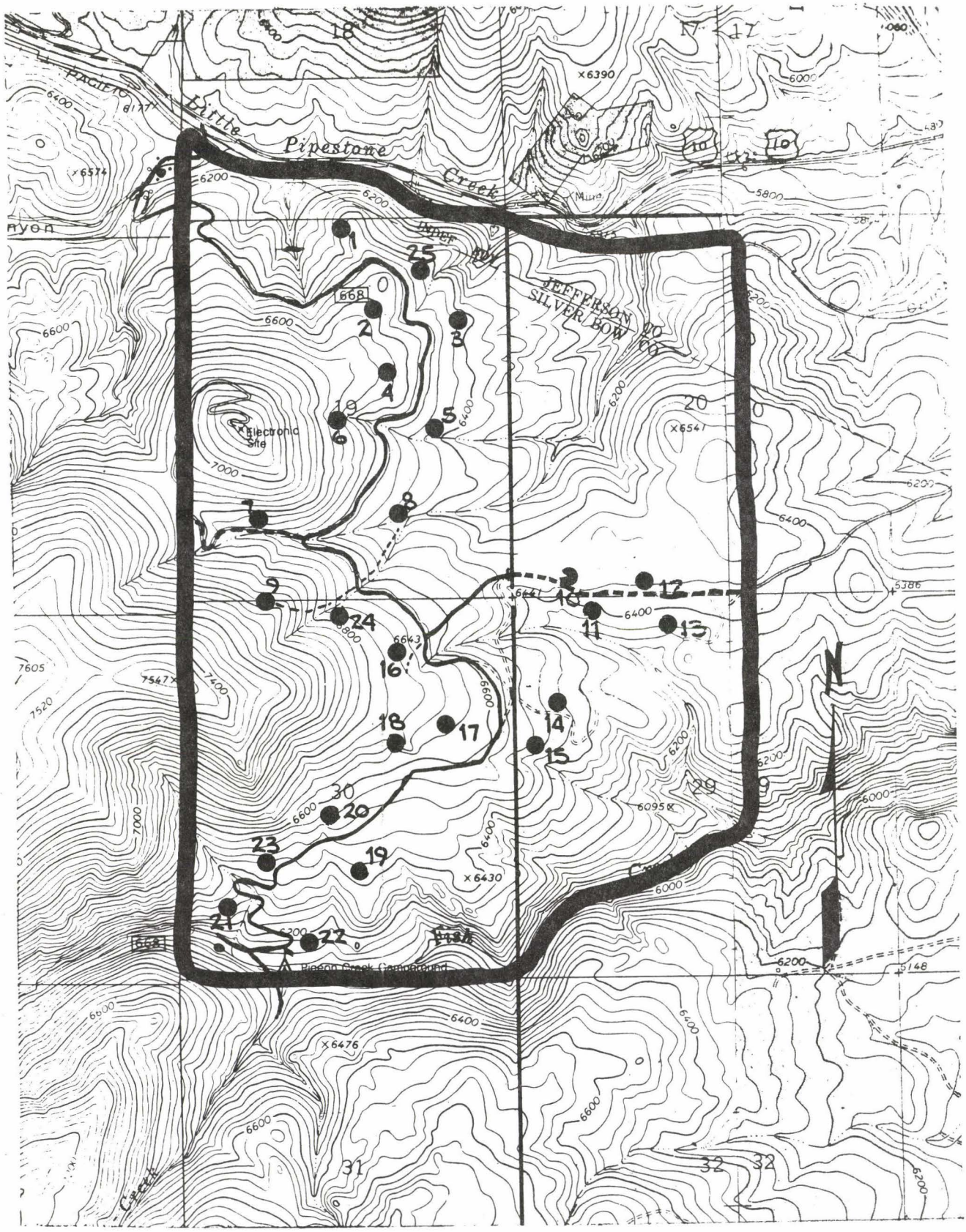
Appendix A4. Cluster locations - Coyote.



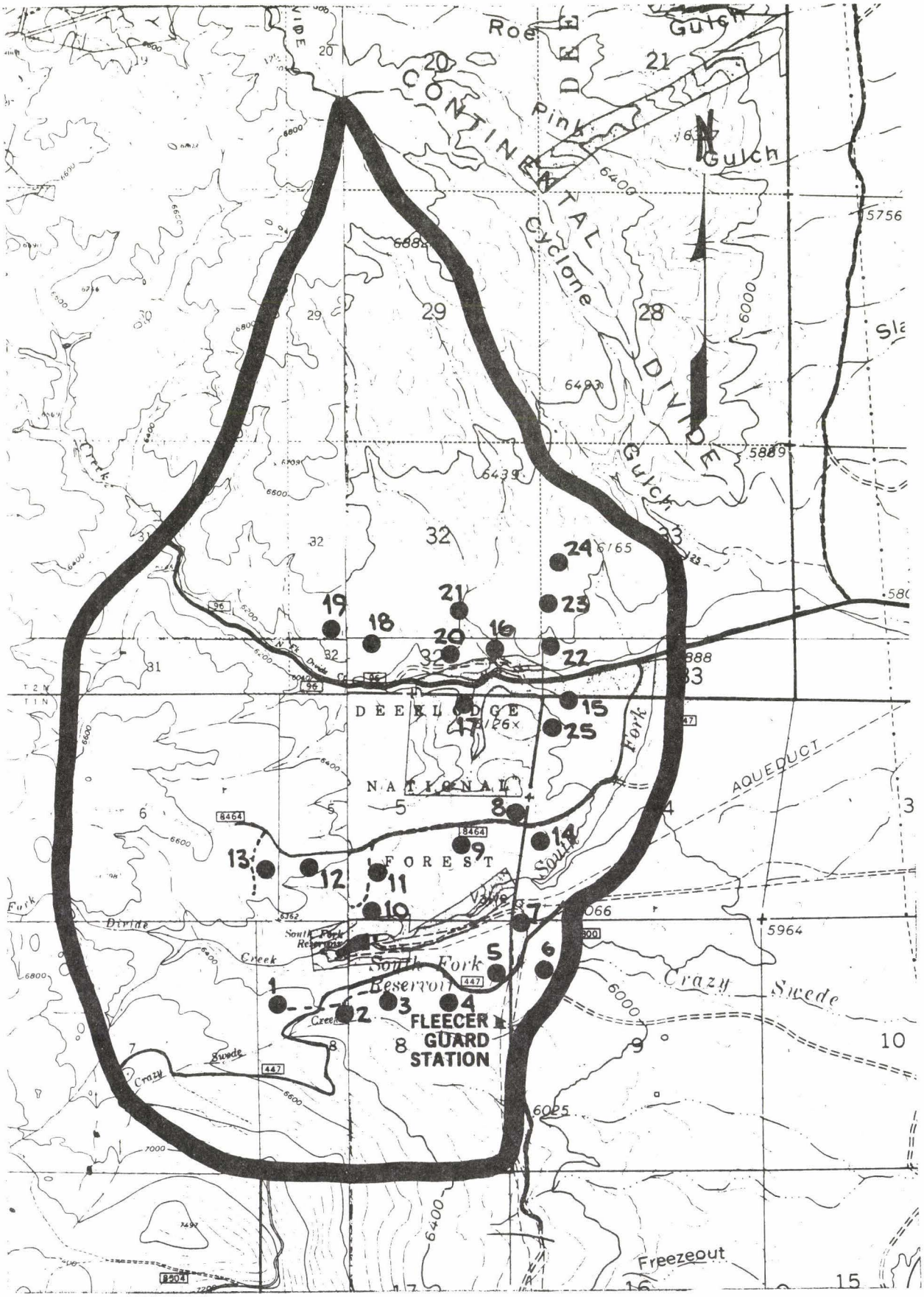
Appendix A5. Cluster locations - Whiskey.



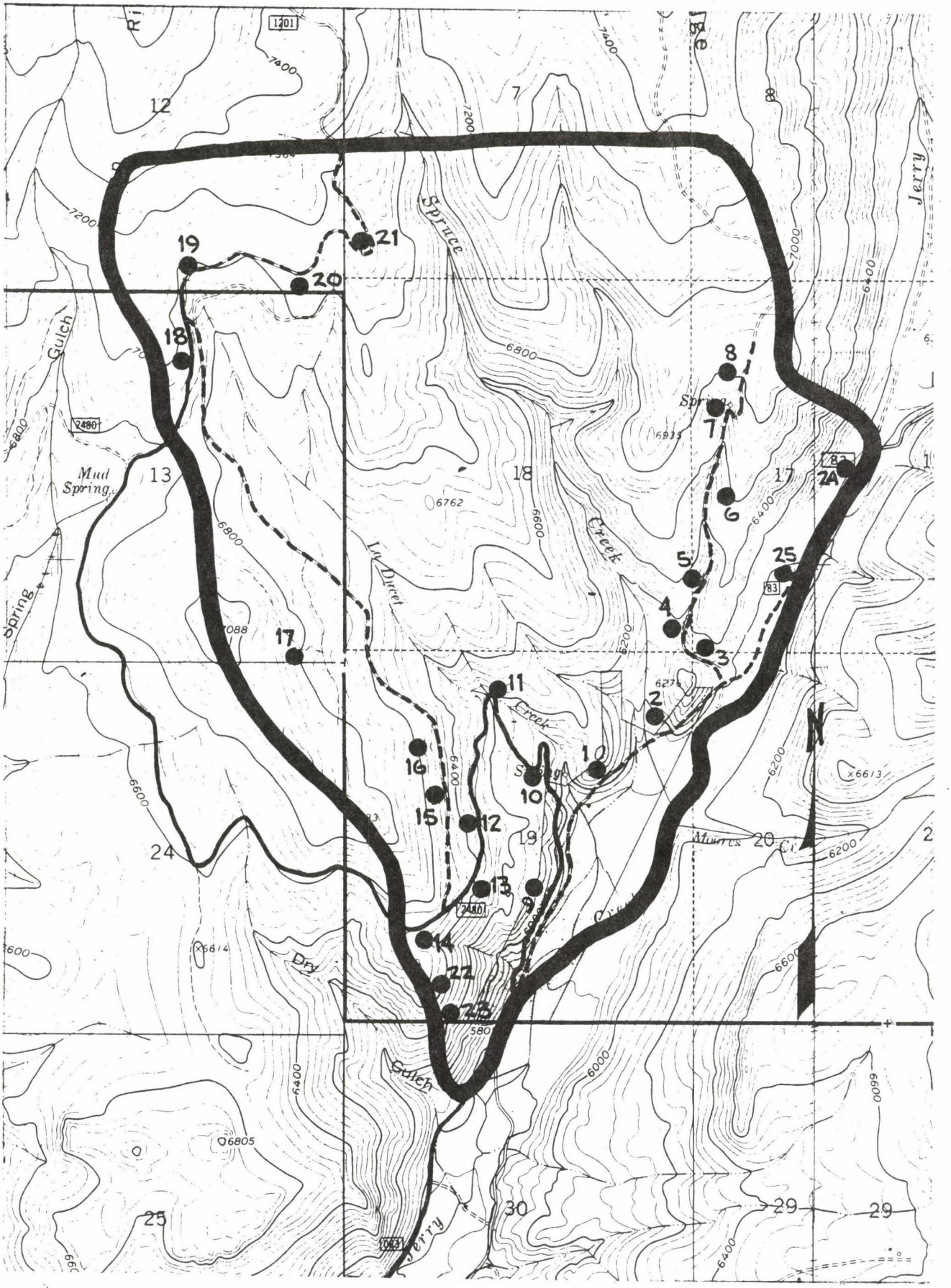
Appendix A6. Cluster locations - Bald.



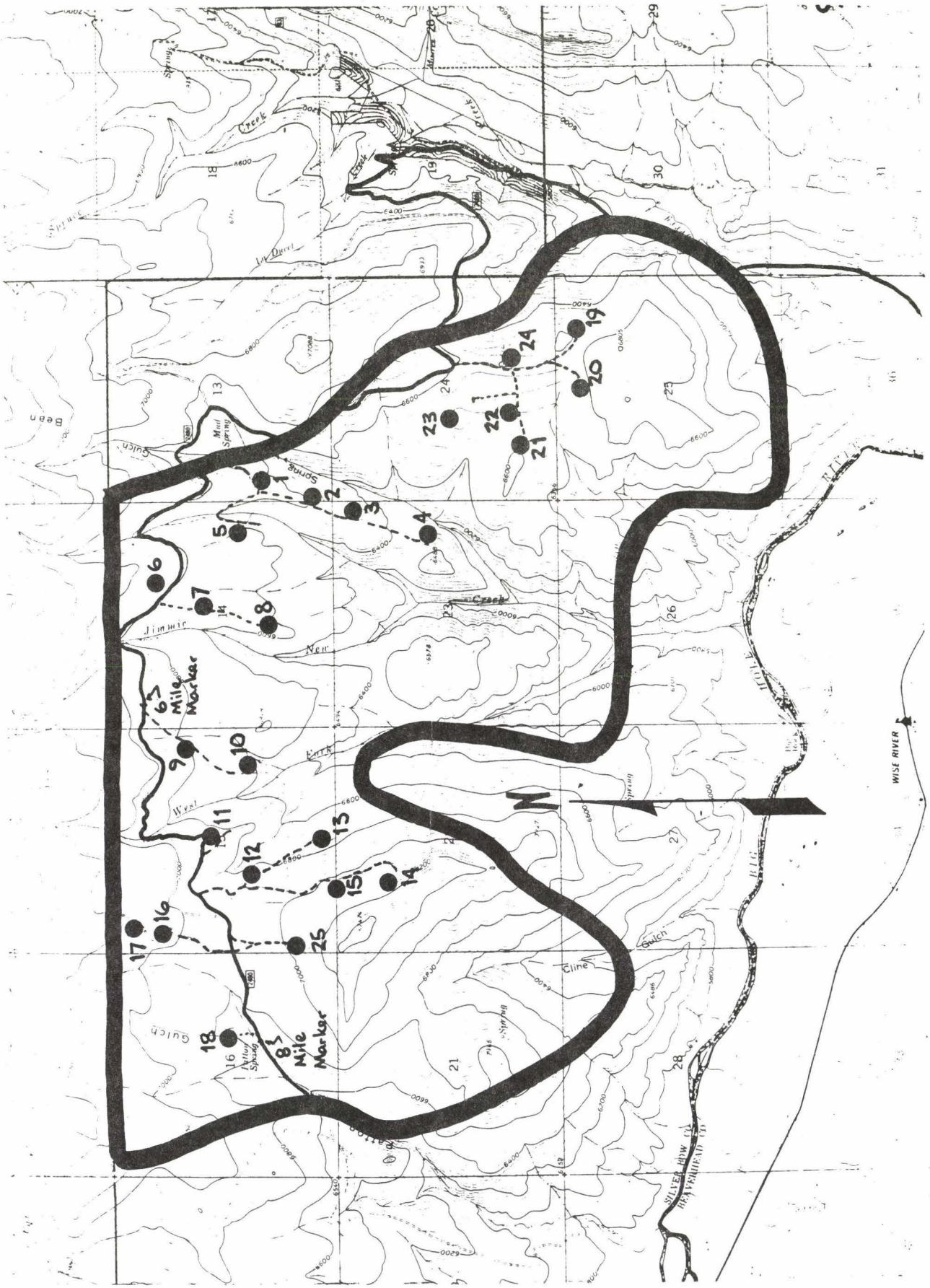
Appendix A7. Cluster locations - Fish.



Appendix A8. Cluster locations - Divide.



Appendix A9. Cluster locations - Jerry.



Appendix A10. Cluster locations - Jimmie.

Appendix B1. Budworm larval development in percent by instars for the three Dipel blocks, 1981.

		Block														
		Grouse					Bald					Jimmie				
		Instar					Instar					Instar				
Date		2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
June	11						60	35	4	0	0	70	30	0	0	0
	12															
	13															
	14															
	15															
	16	36	49	4	0	0	66	32	2	0	0					
	17											90	10	0	0	0
	18															
	19															
	20															
	21	73	19	8	0	0	49	39	12	0	0					
	22											92	7	1	0	0
	23	33	46	20	1	0	32	29	33	6	0					
	24											94	5	1	0	0
	25	15	41	40	4	0	19	33	43	5	0					
	26											70	22	6	2	0
	27	6	27	49	18	0	5	28	38	28	1					
	28		Prespray									64	22	13	1	0
	29		Treat													
	30							Prespray								
July	1							Treat								
	2											6	24	53	17	0
	3															
	4															
	5											Prespray				
												Treat				

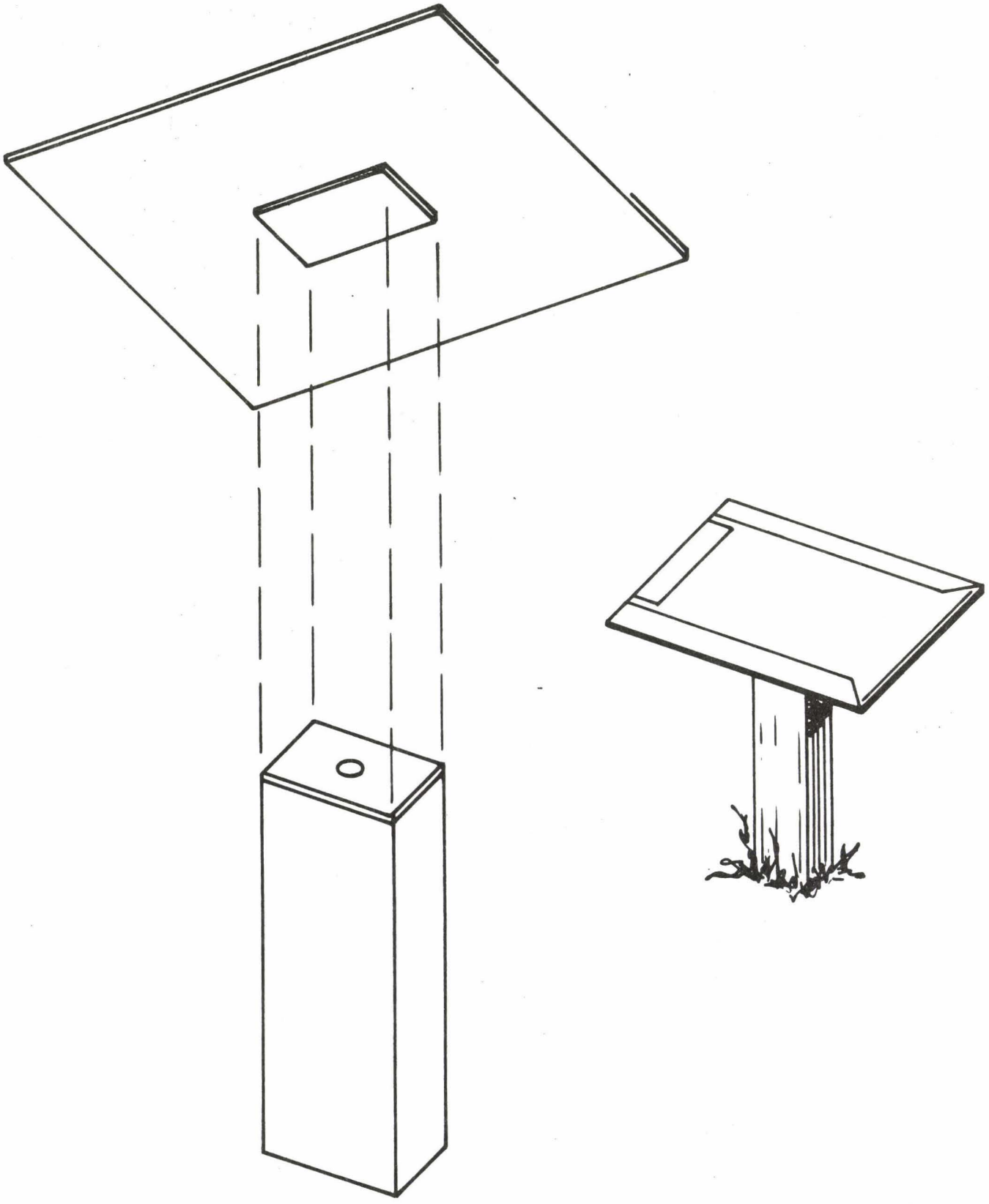
Appendix B2. Budworm larval development in percent by instars for the three Thuricide blocks, 1981.

	Block														
	Spire					Coyote					Whiskey				
	Instar					Instar					Instar				
Date	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
June 11						75	25	0	0	0	37	42	20	1	0
12															
13															
14															
15															
16											58	36	5	0	0
17	65	33	2	0	0	66	32	2	0	0					
18															
19											78	18	3	0	0
20															
21	60	27	13	0	0	57	39	4	0	0					
22											55	31	14	0	0
23	40	36	23	1	0	57	31	12	0	0					
24											36	32	30	2	0
25	17	41	34	8	0	50	37	12	1	0					
26											10	47	30	13	0
27	1	22	50	27	0	33	18	36	13	0					
28											8	33	35	24	1
29	Prespray														
30	Treat														
July 1											Prespray				
2						Prespray					Treat				
3						Treat									

Appendix B3. Budworm larval development in percent by instars for the three control blocks, 1981.

		Block														
		Fish					Divide					Jerry				
		Instar					Instar					Instar				
Date		2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
June	11	71	14	14	0	0						100	0	0	0	0
	12															
	13															
	14															
	15	79	21	0	0	0										
	16						84	14	2	0	0					
	17	91	9	9	9							80	20	0	0	0
	18															
	19															
	20															
	21															
	22	64	33	3	0	0	88	10	2	0	0	93	6	1	0	0
	23															
	24	72	24	4	0	0	62	33	5	0	0	83	17	0	0	0
	25															
	26	66	29	5	0	0	53	23	23	1	0	86	13	1	0	0
	27															
	28	47	20	32	1	0	52	15	31	2	0	49	26	24	1	0
	29															
	30	22	31	38	9	0	22	35	33	10	0					
July	1															
	2											23	32	35	10	0
	3	Prespray														
	4	Treat 1/					Prespray									
	5						Treat 1/									
	6											Prespray				
	7											Treat 1/				

1/ No insecticide was applied to the untreated control blocks.

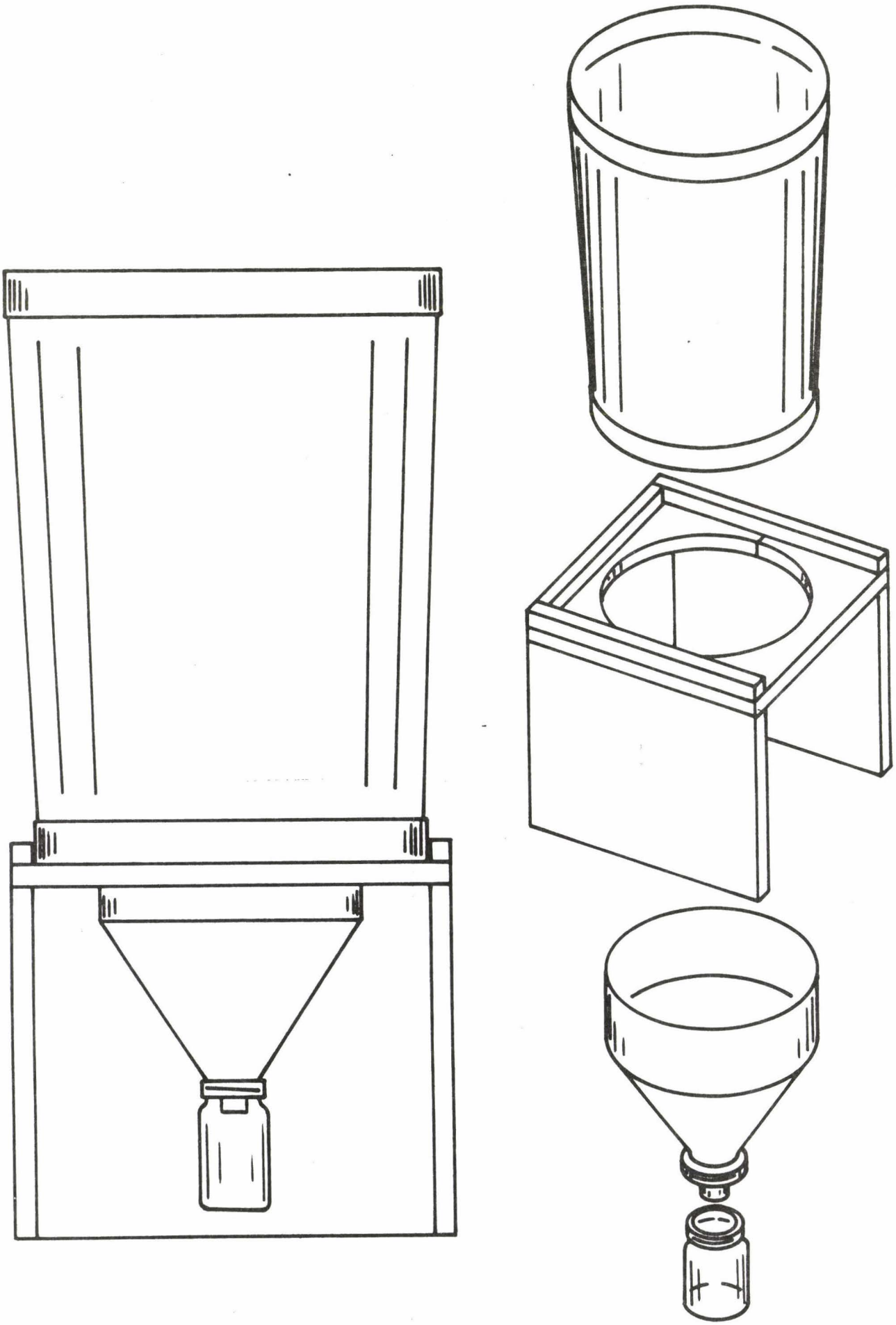


Appendix C. Spray deposit sampler.

Appendix D. Treating and postspray sampling sequence by block, 1981.

Date	Grouse	Spire	Coyote	Whiskey	Bald	Fish	Divide	Jerry	Jimmie
JUNE									
28	Prespray								
29	Treat	Prespray							
30		Treat			Prespray				
JULY					Treat				
1				Prespray	Treat				
2			Prespray	Treat					
3			Treat			Prespray			
4						Treat [1/]	Prespray		Prespray
5							Treat [1/]		Treat
6	7-day							Prespray	
7		7-day						Treat [1/]	
8					7-day				
9				7-day					
10			7-day						
11						7-day			
12							7-day		7-day
13	14-day								
14		14-day						7-day	
15					14-day				
16				14-day					
17			14-day						
18						14-day			
19							14-day		14-day
20	21-day								
21		21-day						14-day	
22					21-day				
23				21-day					
24			21-day						
25						21-day			
26							21-day		21-day
27								21-day	

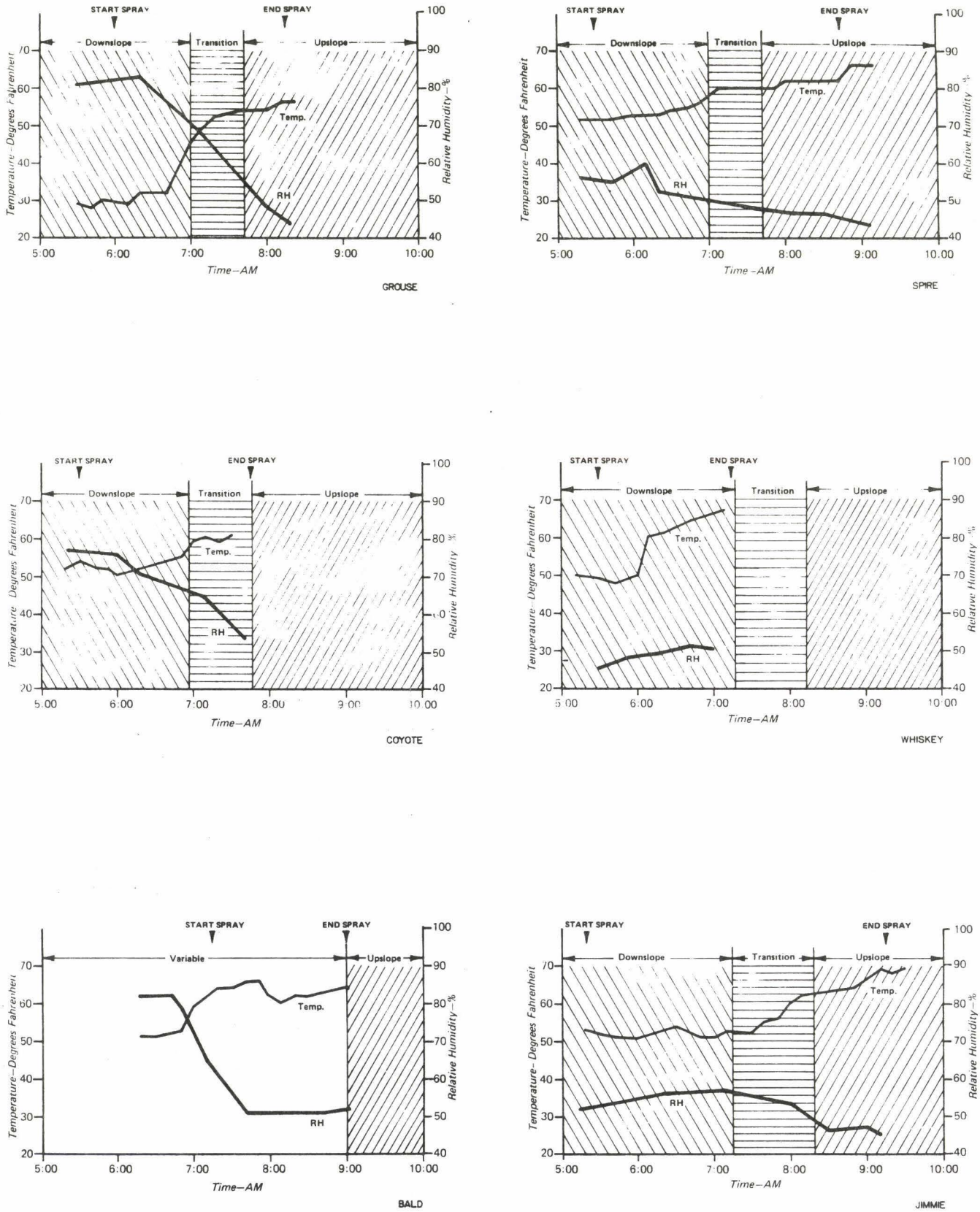
[1/] Control blocks were not treated.



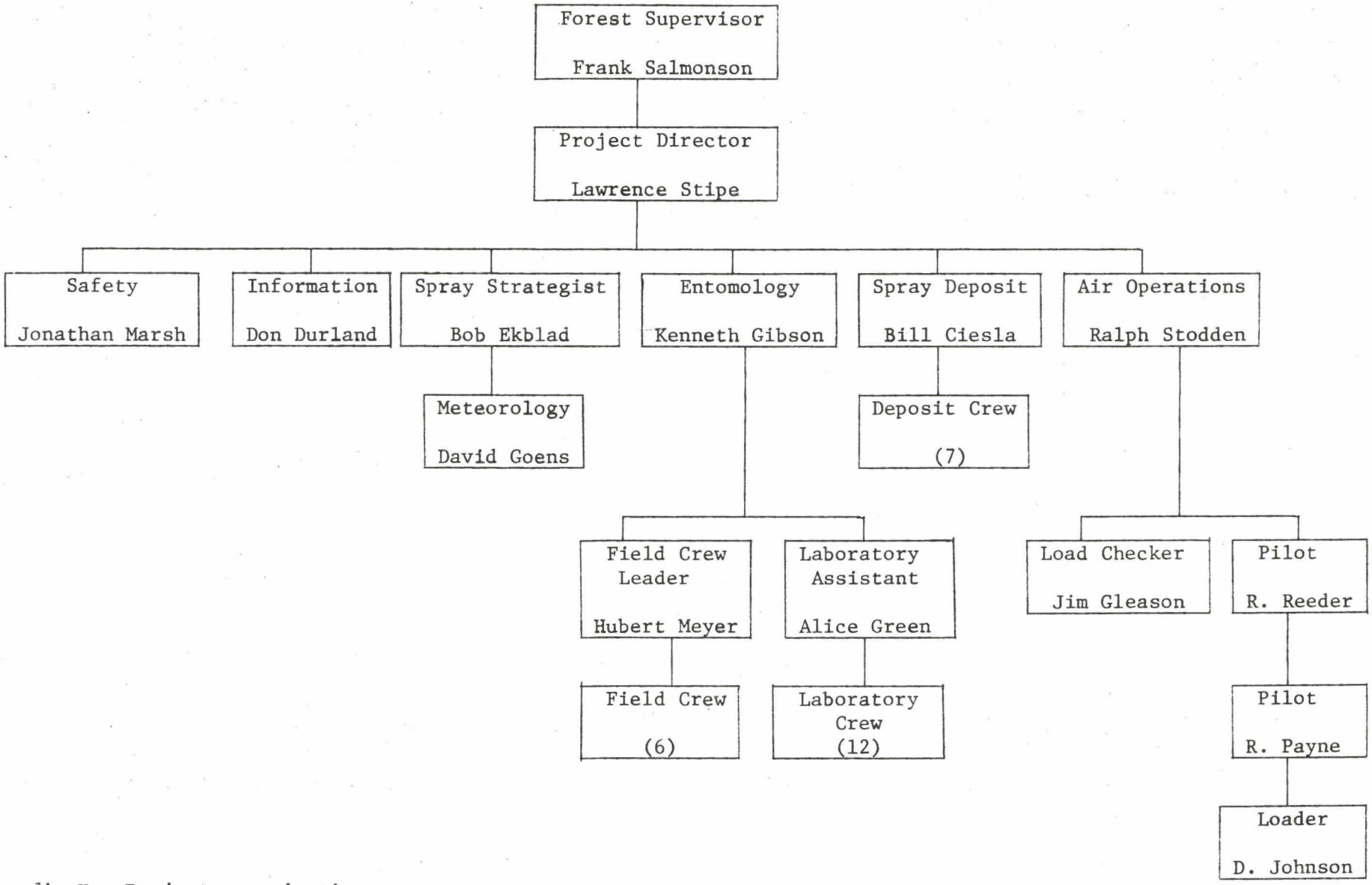
Appendix E. Beating barrel apparatus.

Appendix F. Summary of aircraft characterization trials, 1981.

Nozzle configuration	Tank mix	Air speed in mph (km/hr)	Wind speed in mph (km/hr)	Relative humidity (%)	Temperature in degrees F (degrees C)	Volume median diameter of droplets in microns (inches)	Deposit density 150 ft land drops/cm^2 (drops/in^2)	Deposit density coefficient of variation (%)
3/4 boom	Dipel	146 (235)	2 (3.2)	49	53 (12)	119 (.047)	22.5 (57.2)	50.1
3/4 boom	Dipel	140 (225)	2 (3.2)	52	52 (11)	152 (.060)	23.3 (59.2)	31.8
Full boom	Thuricide	131 (211)	3 (14.8)	57	54 (12)	249 (.098)	45.4 (115.3)	37.5
Full boom	Thuricide	145 (233)	3 (4.8)	57	54 (12)	249 (.098)	25.4 (64.5)	45.6
Full boom	Dipel	138 (222)	2 (3.2)	59	56 (13)	125 (.049)	25.7 (65.3)	36.6
Full boom	Dipel	134 (216)	2 (3.2)	55	57 (14)	122 (.048)	41.6 (105.7)	32.6
3/4 boom	Thuricide	140 (225)	3 (4.8)	45	62 (17)	249 (.098)	23.0 (58.4)	37.8
3/4 boom	Thuricide	132 (212)	5 (8.1)	43	64 (18)	238 (.098)	21.8 (55.4)	23.1



Appendix G. Temperature, relative humidity, and wind direction during spray period, 1981.



Appendix H. Project organization.

Appendix I. Project budget summary.

	Contributed	Project
Aircraft		
Ayers Turbo Thrush (spray)		$ 35,845.00
Bell Jet Ranger (observation)		6,554.00
Cessna 180 (observation)		836.00
		43,235.00
Pesticides		
Dipel® 4L	$20,362.00	40,388.00
Thuricide® 16B	12,825.00	47,925.00
Rhodamine Dye		3,680.00
Acrylocoat®		135.00
	33,187.00	92,128.00
Equipment		
Laboratory	1,383.00	3,556.00
Field	3,650.00	4,638.00
	5,033.00	8,194.00
Transportation		
Vehicle rental	2,321.00	16,227.00
POV mileage		240.00
Common carrier		15.00
Gasoline and oil		2,290.00
	2,321.00	18,772.00
Administration		
Salaries - Region	19,480.00	6,760.00
- Forest	4,165.00	28,162.00
- Other	5,487.00	285.00
Overtime - Region		6,450.00
- Forest		7,693.00
- Other	1,160.00	1,298.00
Per diem - Region		12,785.00
- Forest		570.00
- Other	2,477.00	870.00
	32,769.00	64,873.00
Services		
Spray deposit analysis		1,685.00
Telephone		479.00
Laboratory rental	1,200.00	
Cold storage		150.00
Foliage examination (eggs)		7,236.00
Maps and photography		320.00
Communications		180.00
Data analysis		834.00
	1,200.00	10,884.00
Reports and Information		
Final project report		1,400.00
Environmental analysis		4,680.00
		6,080.00
Forest Overhead		
Deerlodge National Forest		21,500.00
Totals	$74,510.00	$265,666.00
Grand Total		$340,176.00

Appendix J1. Spruce budworm population density and unadjusted mortality, 1981.

Treatment/ Block	Larvae per 100 shoots: Pre Mean	Pre SE	7-day Mean	7-day SE	14-day Mean	14-day SE	21-day Mean	21-day SE	Unadjusted mortality (percent): 7-day	14-day	21-day
DIPEL											
Grouse	5.93	.47	3.51	.38	2.70	.40	3.07	.33	40.8	54.5	48.2
Bald	10.52	.80	7.19	.65	6.58	.79	5.24	.53	31.6	37.5	50.1
Jimmie	7.10	.78	5.13	.71	5.62	.90	3.85	.51	27.8	20.9	45.8
Mean	7.85		5.27		4.97		4.05		32.9	36.7	48.4
THURICIDE											
Spire	8.23	.94	5.17	.55	3.38	.53	3.14	.42	37.2	58.9	61.9
Coyote	8.98	.92	5.23	.53	5.67	.71	3.74	.38	41.8	36.9	58.4
Whiskey	6.45	.54	3.85	.41	2.71	.30	2.22	.33	40.2	48.0	65.6
Mean	7.89		4.75		3.92		3.03		39.8	50.3	61.6
CONTROL											
Fish	3.48	.40	4.34	.44	4.39	.42	3.03	.30	-24.7	-26.2	12.9
Divide	13.48	1.58	15.89	1.63	15.55	1.37	10.19	.87	-17.9	-15.4	24.4
Jerry	11.99	1.28	10.78	1.35	11.61	1.26	8.13	.87	10.1	3.2	32.2
Mean	9.65		10.34		10.52		7.08		- 7.2	- 9.0	26.6

Appendix J2. Other larval population density and unadjusted mortality, 1981.

Treatment/ Block	Larvae per 100 shoots: Pre Mean	Pre SE	7-day Mean	7-day SE	14-day Mean	14-day SE	21-day Mean	21-day SE	Unadjusted mortality (percent): 7-day	14-day	21-day
DIPEL											
Grouse	4.09	.53	2.77	.49	1.65	.30	1.51	.27	32.3	59.7	63.1
Bald	5.49	.40	3.84	.46	2.77	.44	1.71	.31	30.1	49.5	68.9
Jimmie	2.31	.31	2.67	.35	3.13	.48	2.65	.44	-15.6	-35.5	-14.7
Mean	3.96		3.09		2.52		1.96		22.0	36.4	50.5
THURICIDE											
Spire	6.87	.59	4.14	.45	2.84	.40	2.07	.28	39.7	58.7	69.9
Coyote	6.06	.78	3.98	.40	3.95	.47	2.80	.40	34.3	34.8	53.8
Whiskey	4.67	.50	2.67	.35	2.00	.28	1.19	.22	42.8	57.2	74.5
Mean	5.87		3.60		2.93		2.02		38.7	50.1	65.6
CONTROL											
Fish	3.16	.53	3.74	.40	3.81	.38	3.39	.40	-18.6	-20.6	- 7.3
Divide	4.61	.54	5.53	.69	7.55	1.00	6.90	.92	-20.0	-63.8	-50.0
Jerry	2.06	.37	3.15	.49	3.98	.61	3.12	.64	-52.9	-93.2	-51.5
Mean	3.28		4.14		5.11		4.47		-30.8	-55.8	-36.3

Appendix J3. Combined larval population density and unadjusted mortality, 1981.

Treatment/ Block	Larvae per 100 shoots: Pre Mean	Pre SE	7-day Mean	7-day SE	14-day Mean	14-day SE	21-day Mean	21-day SE	Unadjusted mortality (percent): 7-day	14-day	21-day
DIPEL											
Grouse	10.02	.91	6.27	.83	4.34	.67	4.57	.58	37.4	56.7	54.4
Bald	16.01	.89	11.03	.81	9.35	1.09	6.95	.76	31.1	41.6	56.6
Jimmie	9.41	.93	7.80	.84	8.75	1.02	6.50	.64	17.1	7.0	30.9
Mean	11.81		8.37		7.48		6.01		29.1	36.7	49.1
THURICIDE											
Spire	15.10	1.24	9.31	.85	6.21	.82	5.20	.63	38.3	58.9	65.6
Coyote	15.04	1.39	9.21	.87	9.62	1.14	6.54	.67	38.8	36.0	56.5
Whiskey	11.12	.95	6.53	.68	4.71	.52	3.41	.49	41.3	57.6	69.3
Mean	13.75		8.35		6.85		5.05		39.3	50.2	63.3
CONTROL											
Fish	6.64	.78	8.07	.66	8.20	.68	6.42	.56	-21.5	-23.5	3.3
Divide	18.09	1.97	21.43	2.10	23.09	2.06	17.08	1.62	-18.5	-27.6	5.6
Jerry	14.05	1.45	13.93	1.48	15.59	1.28	11.24	1.01	0.9	-11.0	20.0
Mean	12.93		14.48		15.63		11.58		-13.1	-20.7	10.4

Appendix K. Analyses of variance on prespray larval densities for spruce budworm, other, and combined larvae. 1981.

	DF	SS	MS	F	P
Budworm					
Total	8	79.31			
Treatment	2	6.34	3.17	0.26	>.10
Error	6	72.98	12.16		
	Dipel - a	Thuricide - a		Control - a	
Other					
Total	8	21.63			
Treatment	2	10.80	5.40	2.99	>.10
Error	6	10.83	1.80		
	Control - a	Dipel - a		Thuricide - a	
Combined					
Total	8	110.14			
Treatment	2	5.69	2.84	0.16	>.10
Error	6	104.45	17.41		
	Dipel - a	Control - a		Thuricide - a	

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix L. Spray deposit summary.

	Block					
	Grouse	Spire	Coyote	Whiskey	Bald	Jimmie
Mass median diameter in µm (inches)	228 (.090)	304 (.120)	389 (.153)	308 (.121)	237 (.093)	214 (.084)
Mass mean diameter in µm (inches)	249 (.098)	344 (.135)	426 (.168)	337 (.133)	256 (.101)	232 (.091)
No. median	40	82	95	89	47	41
No. mean	59	101	122	109	71	60
Drops/sq cm (drops/sq in)	14 (36)	13 (33)	16 (40)	13 (33)	6 (15)	13 (33)
Gallons/acre (liters/ hectare)	.08 (.75)	.26 (2.43)	.64 (5.98)	.32 (2.99)	.06 (.56)	.08 (.75)

Appendix M1. Analyses of covariance and Student-Newman-Keuls tests on 7-day postspray larval densities for spruce budworm, other and combined larvae, 1981.

	DF	SS	MS	F	P
Budworm					
Total	8	132.11			
Bet. trt.	2	24.56	12.28	7.58	.05> α >.01
Within	5	8.10	1.62		
Covariate	1	99.45			
Thuricide-a		Dipel-a	Control-b		α = .05
Other					
Total	8	6.86			
Bet. trt.	2	4.33	2.16	9.38	.05> α >.01
Within	5	1.15	0.23		
Covariate	1	1.38			
Thuricide-a		Dipel-a	Control-b		α = .05
Combined					
Total	8	181.35			
Bet. trt.	2	76.62	38.31	15.28	<.01
Within	5	12.54	2.51		
Covariate	1	92.19			
Thuricide-a		Dipel-ab	Control-b		α = .01

Note: Treatment followed by different letters (a, or b) are significantly different.

Appendix M2. Analyses of covariance and Student-Newman-Keuls tests on 14-day postspray larval densities for spruce budworm, other, and combined larvae, 1981.

	DF	SS	MS	F	P
Budworm					
Total	8	152.47			
Bet. trt.	2	36.37	18.19	12.21	.05> α >.01
Within	5	7.45	1.49		
Covariate	1	108.65			
Thuricide-a		Dipel-a	Control-b		α = .01
Other					
Total	8	23.71			
Bet. trt.	2	14.15	7.07	3.74	>.10
Within	5	9.47	1.89		
Covariate	1	0.09			
Thuricide-a		Dipel-a	Control-a		
Combined					
Total	8	282.35			
Bet. trt.	2	148.09	74.05	10.57	.05> α >.01
Within	5	35.04	7.01		
Covariate	1	99.22			
Thuricide-a		Dipel-a	Control-b		α = .05

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix M3. Analyses of covariance and Student-Newman-Keuls tests on 21-day postspray larval densities for spruce budworm, other, and combined larvae, 1981.

	DF	SS	MS	F	P
Budworm					
Total	8	57.99			
Bet. trt.	2	12.68	6.34	29.24	<.01
Within	5	1.08	0.22		
Covariate	1	44.23			
Thuricide-a		Dipel-a	Control-b		α = .01
Other					
Total	8	23.26			
Bet. trt.	2	13.79	6.89	3.85	.10> α >.05
Within	5	8.96	1.79		
Covariate	1	0.51			
Thuricide-a		Dipel-a	Control-b		α = .10
Combined					
Total	0	139.74			
Bet. trt.	2	78.56	39.28	12.96	.05> α >.01
Within	5	15.15	3.03		
Covariate	1	46.03			
Thuricide-a		Dipel-a	Control-b		α = .05

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix N. Adjusted mortality at 21 days using analysis of covariance and Abbott's formula, 1981.

Method	Adjusted mortality (percent)					
	Budworm		Other		Combined	
	Dipel	Thuricide	Dipel	Thuricide	Dipel	Thuricide
Unadjusted	48	62	51	65	49	63
Covariance	30	47	57	72	37	60
Abbott's	30	48	64	75	43	59

Appendix O. Analyses of covariance and Student-Newman-Keuls tests on rearing survival and Residual-population of all defoliators, 1981.

	DF	SS	MS	F	P
Rearing Survival					
Total	8	2259.94			
Bet. trt.	2	245.91	1228.45	60.28	<.01
Within	5	101.90	20.38		
Covariate	1	2212.13			

Thuricide-a	Dipel-a	Control-b	α = .01

Residual Population					
Total	8	74.82			
Bet. trt.	2	54.69	27.32	15.83	<.01
Within	5	8.64	1.73		
Covariate	1	11.49			

Thuricide-a	Dipel-a	Control-b	α = .01

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix P. Analysis of variance on percent parasitism for all defoliators in the 21-day postspray collection, 1981.

	DF	SS	MS	F	P
Total	8	128.42			
Treatment	2	61.06	30.53	2.72	>.10
Error	6	67.37	11.23		

Thuricide-a Dipel-a Control-a

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix Q. Analysis of covariance and Student-Newman-Keuls test for percent defoliation, 1981.

	DF	SS	MS	F	P
Total	8	1347.75			
Bet. trt.	2	358.26	179.13	5.01	.10> α >.05
Within	5	178.75	35.75		
Covariate	1	810.74			

Dipel-a	Thuricide-a	Control-b	α = .10

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix R. Analyses of covariance for spruce budworm egg mass density and number of eggs, 1981.

	DF	SS	MS	F	P
Egg Mass Density					
Total	8	2077.46			
Bet. trt.	2	418.54	209.27	2.00	>.10
Within	5	523.69	104.74		
Covariate	1	1135.23			

Thuricide-a Dipel-a Control-a

Number of Eggs					
Total	8	6862287.20			
Bet. trt.	2	1295735.33	647867.66	1.35	>.10
Within	5	2396684.09	479336.83		
Covariate	1	3169867.78			

Thuricide-a Dipel-a Control-a

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix S. Analyses of covariance and Student-Newman-Kuels tests on larval density for budworm, other, and combined larvae, 1982.

	DF	SS	MS	F	P
Budworm					
Total	8	318.36			
Bet. trt.	2	84.81	42.41	2.84	>.10
Within	5	74.63	14.93		
Covariate	1	158.92			
Thuricide-a		Dipel-a	Control-a		
Other					
Total	8	52.94			
Bet. trt.	2	37.05	18.52	6.51	.05> α >.01
Within	5	14.23	2.85		
Covariate	1	1.66			
Thuricide-a		Dipel-a	Control-b		α = .05
Combined					
Total	8	390.48			
Bet. Trt.	2	180.64	90.32	4.83	.10> α >.05
Within	5	93.59	18.72		
Covariate	1	116.25			
Thuricide-a		Dipel-a	Control-b		α = .10

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix T. Analyses of variance and Student-Newman-Kuels tests for percent female pupae, percent female adults, and average weight of female pupae, 1982.

	DF	SS	MS	F	P
% Female Pupae					
Total	8	440.42			
Treatment	2	297.81	148.90	6.26	.05> α >.01
Error	6	142.61	23.77		
Control-a		Thuricide-b	Dipel-b		α = .05
% Female Adults					
Total	8	293.95			
Treatment	2	172.71	86.35	4.66	.10> α >.05
Error	6	111.24	18.54		
Control-a		Dipel-b	Thuricide-b		α = .10
Weight of Female Pupae					
Total	8	916.06			
Treatment	2	233.23	116.62	1.02	> .10
Error	6	682.83	113.81		
Thuricide-a		Dipel-a	Control-a		

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix U. Analysis of variance and Student-Newman-Keuls test on percent parasitism of spruce budworm, 1982.

	DF	SS	MS	F	P
Total	8	33.46			
Treatment	2	19.05	9.52	3.96	.10> α >.05
Error	6	14.41	2.40		

Dipel-a Control-ab Thuricide-b α = .10

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix V. Analyses of variance and Student-Newman-Keuls tests on average percent of total parasitsm by species, 1982.

	DF	SS	MS	F	P
Apanteles spp.					
Total	8	36.94			
Treatment	2	31.49	15.74	17.32	< .01
Error	6	5.45	0.91		
Dipel-a		Control-a	Thuricide-b		α = .01
Glypta fumiferanae					
Total	8	24.25			
Treatment	2	4.14	2.07	0.62	> .10
Error	6	20.11	3.35		
Thuricide-a		Dipel-a	Control-a		
Phaeogenes hariolus					
Total	8	11.14			
Treatment	2	8.96	4.48	12.23	< .01
Error	6	2.18	0.36		
Dipel-a		Control-ab	Thuricide-b		α = .01
Cermoasia auricaudata					
Total	8	1.18			
Treatment	2	0.86	0.43	8.06	.05> α >.01
Error	6	0.32	0.05		
Dipel-a		Thuricide-a	Control-b		α = .05
Madremyia saundersii					
Total	8	8.30			
Treatment	2	0.22	0.11	7.46	.05> α >.01
Error	6	0.09	0.01		
Dipel-a		Thuricide-a	Control-b		α = .05

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix W. Analysis of covariance and Student-Newman-Keuls test for percent defoliation, 1982.

	DF	SS	MS	F	P
Total	8	3780.02			
Bet. trt.	2	2978.27	1489.14	35.12	< .01
Within	5	212.02	42.40		
Covariate	1	589.73			

Thuricide-a	Dipel-a	Control-b	α = .01

Note: Treatments followed by different letters (a, or b) are significantly different.

Appendix X. Analyses of covariance for spruce budworm egg mass density and number of eggs, 1982.

	DF	SS	MS	F	P
Egg Mass Density					
Total	8	5805.36			
Bet. Trt.	2	1939.70	969.85	1.80	>.10
Within	5	2687.77	537.55		
Covariate	1	1177.89			

Thuricide-a Dipel-a Control-a

Number of Eggs					
Total	8	22048700.28			
Bet. Trt.	2	8159582.58	4079791.29	2.07	>.10
Within	5	9841610.96	1968322.19		
Covariate	1	4047506.74			

Thuricide-a Dipel-a Control-a

Note: Treatments followed by different letters (a, or b) are significantly different.

This report describes project results involving pesticides. It contains recommendations for their use. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers

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